A CAHNERS PUBLICATION SEPTEMBER 20, 1976

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3 months

EDN

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

µP Design Series details MONITOR/DEBUG software

Sampling comparator simplifies ADC design

Panel meters: Is what you read, what you need?

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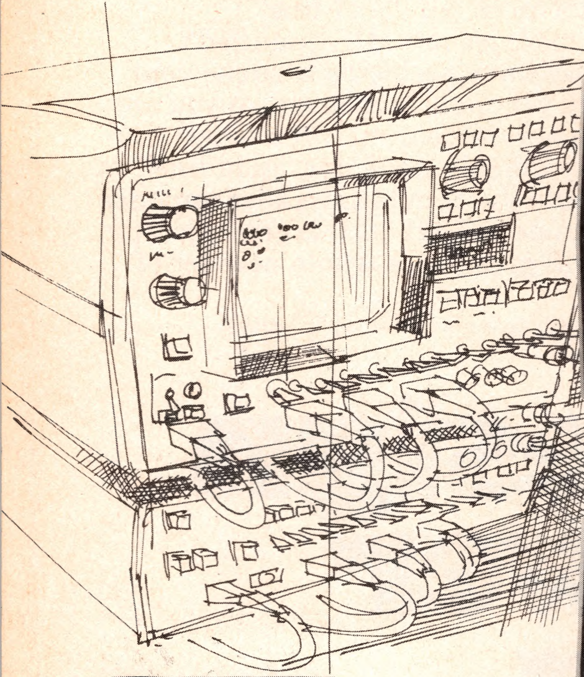
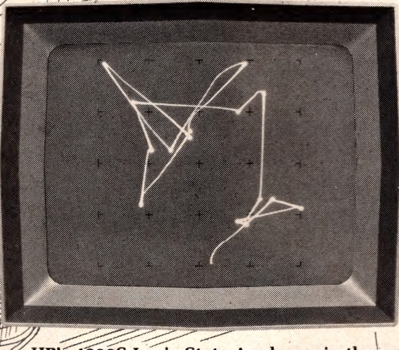
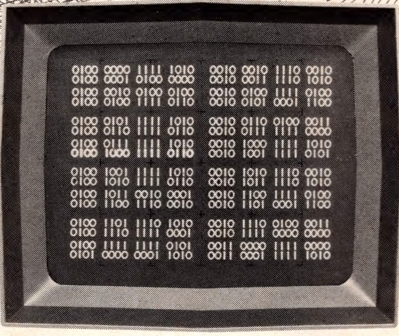
Let's talk about the easy way for you to spot microprocessor
HARDWARE PROBLEMS





HP's 1600S Logic State Analyzer, in the MAP mode, lets you examine the unique "fingerprint" of every logic system.



In the TABLE mode, the 1600S displays up to 16 32-bit words. These words could be combinations of addresses, instructions or states of the control lines.

We've probably both spent hours at the simulator to prove we had good software and then discovered the hardware won't play—what do we do? You know the traditional answer. Dig out the scope, get out the program printout, and brace yourself for hours of grinding, point-by-point checks. But I can tell you that doesn't have to be the case. Especially now that HP has introduced some new tools that can really cut down your troubleshooting time.

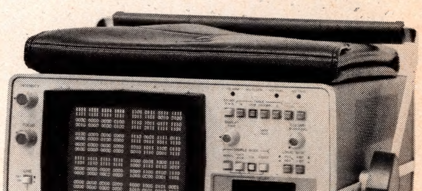
HP's Logic State Analyzers can really take a lot of pain out of your troubleshooting procedures. You'll find wiring errors, defective components, and even solder splashes; and you'll find them a lot more quickly than ever before.

Let me give you an example. We had an eight-bit microprocessor system with start-up problems. The clocks were running and phased right, and the address lines toggled, but the machine didn't function. So, we set up an HP 1600S Logic State Analyzer to look at both the Address and Data buses. It was then we noticed that only "zeros" were being fetched from memory. Knowing the ROM was good, we then added several control lines to the display and the problem showed up immediately. The "Enable" line never went high. A quick look at the "Enable" driver showed the input was ok, but no output. Obviously, the gate was defective.

I don't know how long it would have taken to find that one without HP's Logic State Analyzers, but I *know* it would have taken us a lot longer.

Call your local HP field engineer. He'll give you all the details on the 1600S (priced at $7100*) including spec sheets and application notes detailing the use of mapping for troubleshooting minicomputer and microprocessor systems. He'll tell you about the seminars that HP has arranged around the country and tell you when one will be held in your area and how you can attend. You ought to go to one, because you'll discover an exciting new concept in digital troubleshooting.

*Domestic U.S.A. price only.



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SEPTEMBER 20, 1976
VOLUME 21, NUMBER 17

EDN

EXCLUSIVELY FOR DESIGNERS AND
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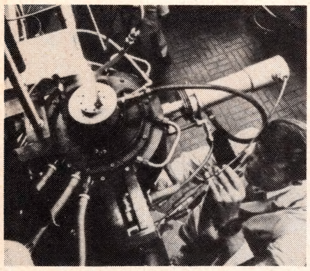
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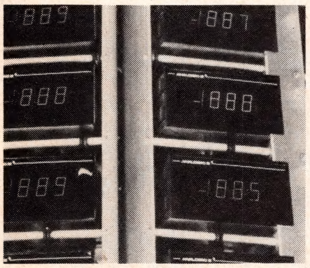
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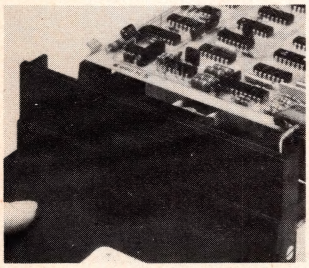
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COVER

Analog, digital or digilog? Most manufacturers agree that the final application will determine the meter technology best suited to your design. We thank Datel Systems, Inc. for their imaginative cover photo combining the best of all worlds. Our "experts' views" story begins on pg. 40.

BPA ABP

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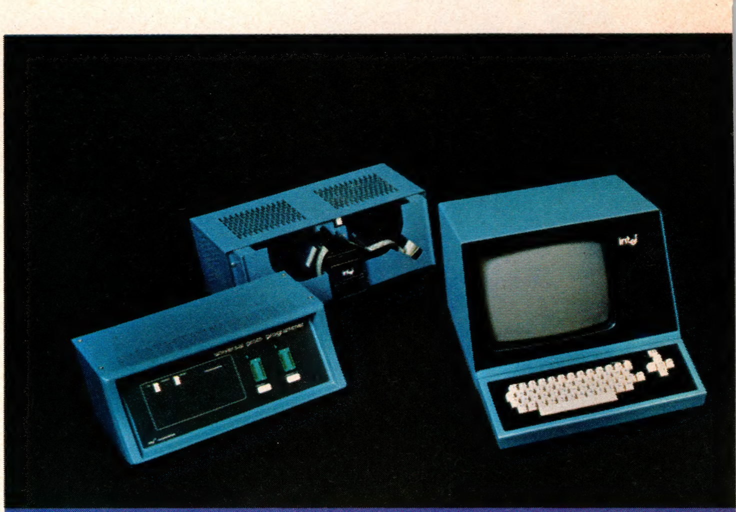
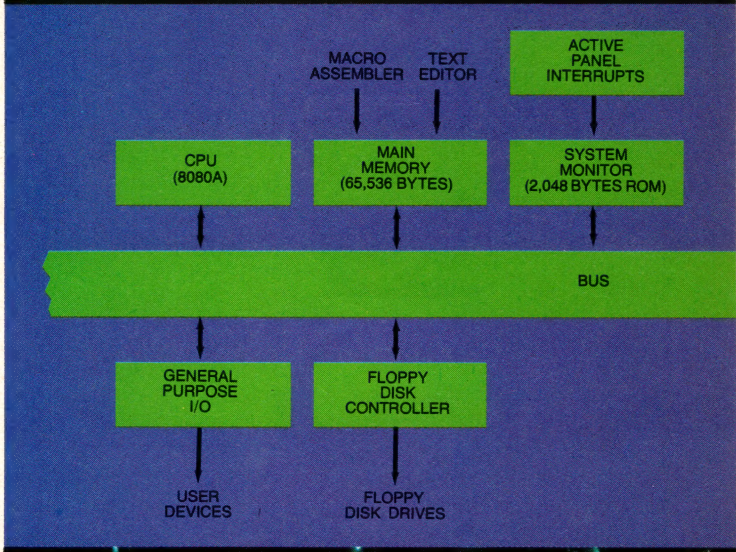
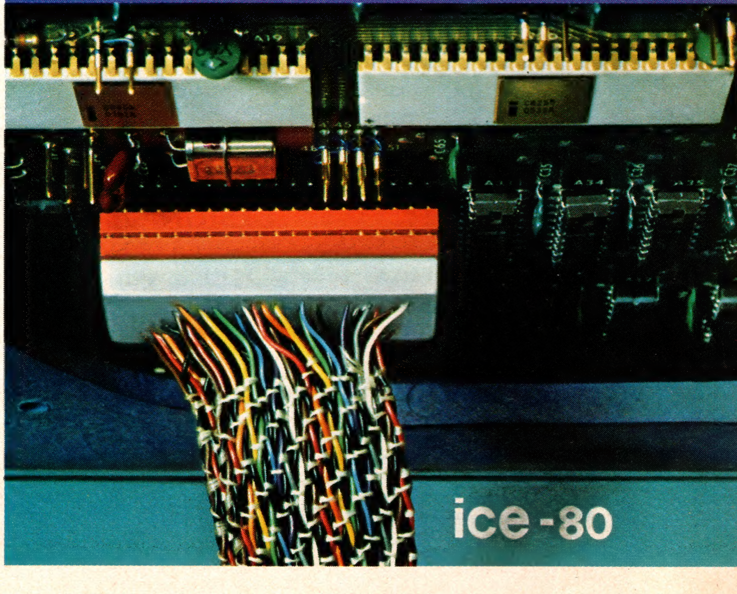
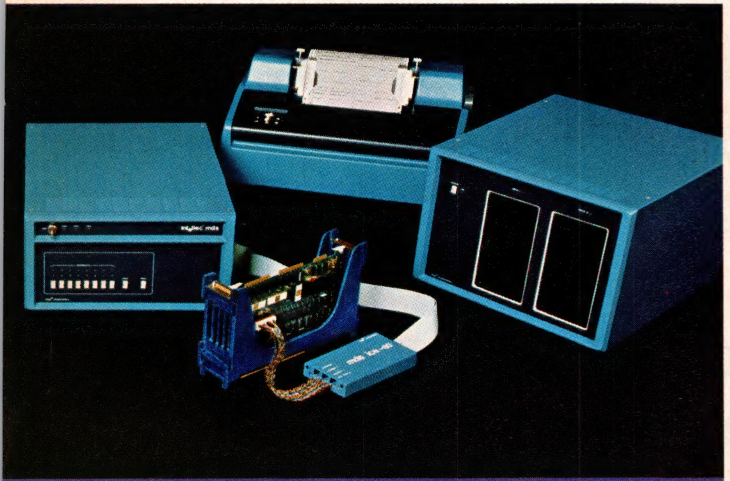
With ICE-80 and ICE-30 Intellec's in-circuit emulation modules, you exercise your complete hardware/software prototype under control of high level diagnostic software. ICE-80 plugs into the 8080 socket in your prototype system and runs it in real time. Under Intellec system control, you single-step your system program, using Intellec's memory and I/O as though they were part of the prototype system. Powerful debug functions are extended into your system and you can examine or modify your system memory or Intellec memory using symbolic references instead of machine addresses.

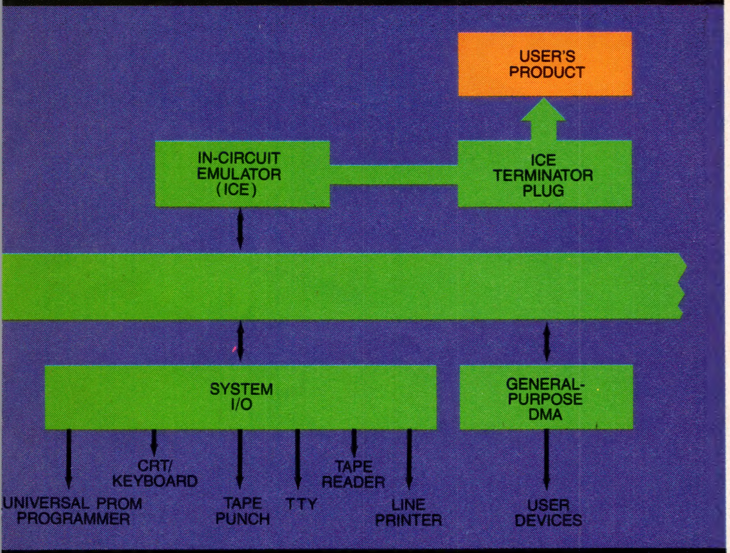


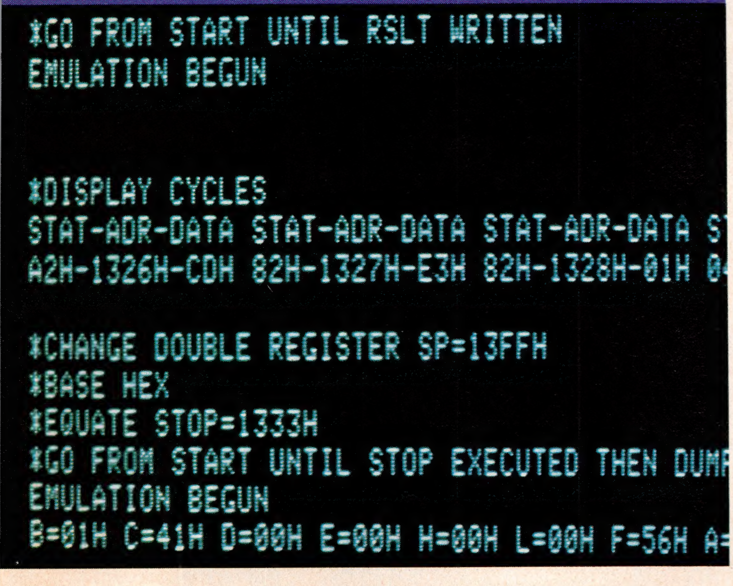




lets you see what your it's still on the bench.







```
*GO FROM START UNTIL RSLT WRITTEN
EMULATION BEGUN


*DISPLAY CYCLES
STAT-ADR-DATA STAT-ADR-DATA STAT-ADR-DATA S
A2H-1326H-CDH 82H-1327H-E3H 82H-1328H-01H 0

*CHANGE DOUBLE REGISTER SP=13FFH
*BASE HEX
*EQUATE STOP=1333H
*GO FROM START UNTIL STOP EXECUTED THEN DUM
EMULATION BEGUN
B=01H C=41H D=00H E=00H H=00H L=00H F=56H A=
```

The Intellec system includes its own 8080 processor, memory, and a full range of peripherals designed to ease your development task. These include diskette operating system, CRT/keyboard, line printer, universal PROM programmer, high speed papertape reader, the in-circuit emulation modules, (ICE-80 and ICE-30) and interfaces for teletypewriter and high speed tape punch.

Under Intellec software you assemble, edit, execute and debug programs quickly. The diskette-based operating system, ISIS, performs all your program and file management tasks automatically. A wide range of system commands gives you complete control of your prototype, including the ability to set multiple hardware and software break point conditions.

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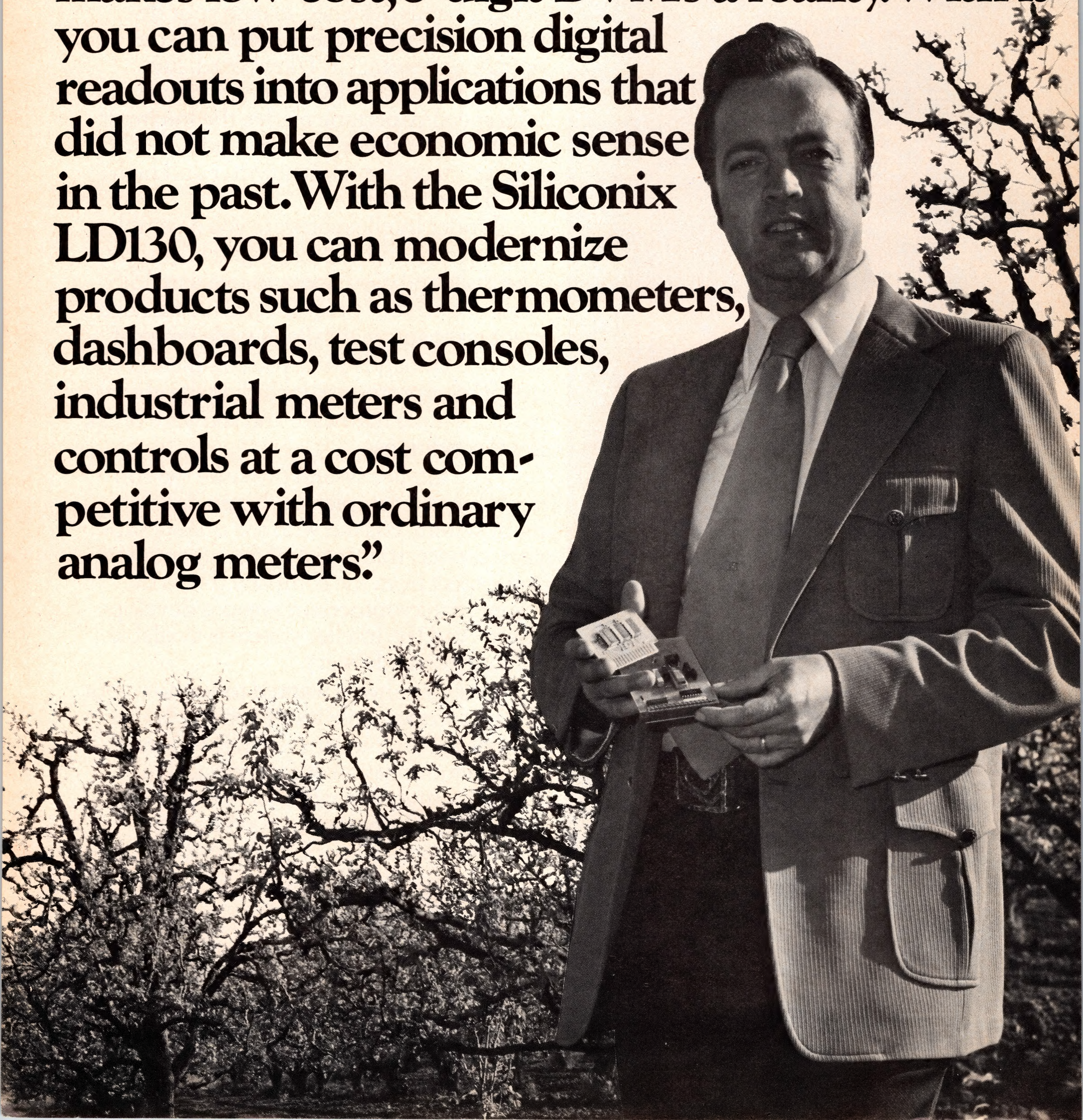
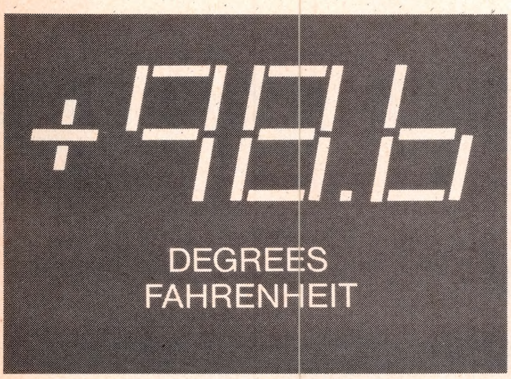
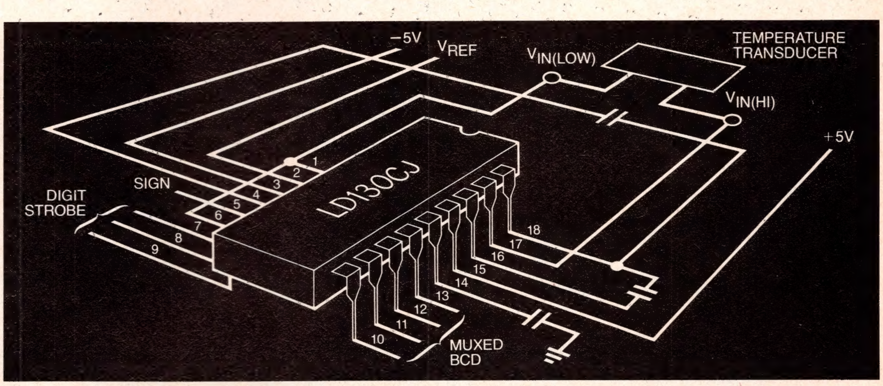


quality digital meter a cheap analog meter."





"At Siliconix, we call the LD130 'everyman's digital voltmeter chip'.

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"Automatic zeroing, automatic polarity outputs, and auto-ranging outputs eliminate zero adjust potentiometers, switch the ± sign, and allow automatic control of decimal points and range scaling resistors.

"±5V CMOS construction enables the LD130 to operate efficiently with any standard CMOS or TTL logic. The multiplexed BCD outputs are easily interfaced with 'intelligent' microprocessor-based systems. This format is also ideal for the widest range of digital displays.

"Accuracy is ±0.1% of reading ±1 count. Accuracy is maintained automatically by Siliconix' exclusive quantized feedback design (patent applied for) which continuously corrects for zero drift. This same feature has made the Siliconix ±3-1/2 digit LD110/LD111 DVM set the most widely used by designers of professional instruments and control systems.

"Just as important, the LD130 is easy and inexpensive to use. Unlike most DVMs, it requires no precision resistors and capacitors, no external temperature compensation, no dual tracking references, no operational amplifiers or input buffers. These have been eliminated by state-of-the-art chip design.

"Since only low-cost components are needed with the 18-pin LD130, it allows complete meter/display subsystems to be built into products for less than $15 (1K quantities).

"The LD130 is your opportunity to create new products and upgrade your present ones. Now you can build a quality digital meter for your system at a cost you can afford."

To order the LD130CJ ($8.75 at 100 lot), contact our franchised distributors: Components Plus, Elmar, Hamilton/Avnet, Pioneer, Quality Components, Semiconductor Specialists, or R. A. E. For more details, call or write Siliconix, 2201 Laurelwood Road, Santa Clara, California 95054, (408) 246-8000.

Siliconix incorporated

Announcing a BiMOS breakthrough...

The RCA 3140: most useful op amp since the 741.

For the price of a 741 you get a lot more op amp. MOS/FET input makes the difference.

Every so often a new advance greatly expands op amp versatility. In 1965 there was the general-purpose 702. Followed in 1966 by the 709, with higher voltage, gain and input impedance. Along came the 101 with still higher voltage and gain. Then in 1968 the remarkable 741 gave you the added benefits of on-chip compensation and low cost.

Now, RCA announces a new giant step toward the ideal op amp. The CA3140 Series of BiMOS op amps.

It gives you the big advantages of MOS/FET input...*plus* bipolar speed and high supply voltage operating capability: 4 to 44 V, dual or single supply. That means very high input impedance: 1.5 TΩ typ. Very low input current: 10 pA typ. at ±15 V. Low input offset voltage: as low as 2 mV max. Wide common-mode input voltage range—can be swung 0.5 V below negative rail. In addition, output swing complements input common-mode range, permitting full utilization of low supply voltages (down to 4 V). And PMOS input devices are protected by rugged bipolar diodes.

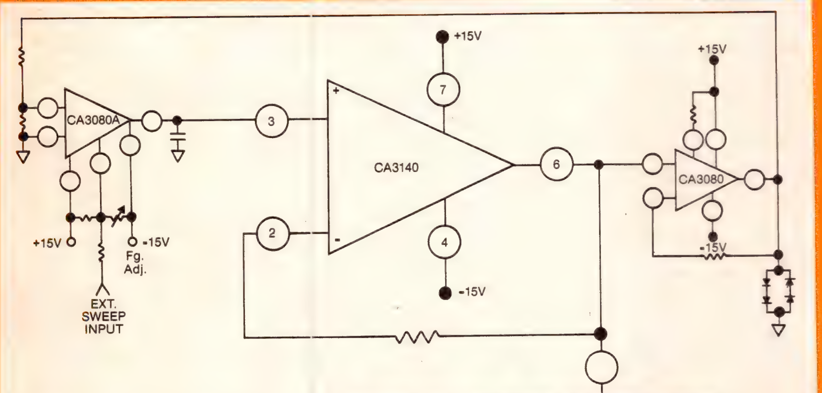
BiMOS vs. 741

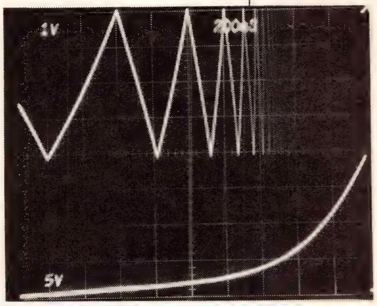
You get all of those features for the price of a 741. 69 cents at the 100 unit level for the CA3140T, S. Plus big circuit savings. BiMOS minimizes bias circuitry. Allows single supplies in portable, automotive and instrumentation equipment.

BiMOS vs. BI-FET

Compared to recently announced higher-priced BI-FET types, the CA3140 offers lower input currents, higher input resistance, improved offset current and comparable offset voltage—all with high slew rate and bandwidth. So chances are, you don't have to pay the higher prices.

In fact, in most existing circuits using premium op amps, the CA3140 permits cost reductions and/or improved performance with minimum circuit redesign. And if you have an application where you ruled out op amps altogether because of cost...reconsider. The CA3140 is cost effective in many places where other op amps are not.





Basic Function Generator

The CA3140 gives 1,000,000:1 range, single control when used as a buffer readout for the integrating capacitor in this basic function generator. The RCA data sheet (File No. 957) tells you how to build this circuit.

Low circuit cost

The CA3140 needs no external compensating circuitry. It is characterized for low-cost TTL systems requiring operation at 5 V and maintains operation down to 4 V. Its wide bandwidth—4.5 MHz unity gain—makes possible low-cost video and audio circuits. For low-cost sample and hold and other data acquisition systems, it offers fast settling time: 1.4 μs typ. to 10 mV. When it's driving power transistors, the output swings to within 0.2 V of the negative supply, eliminating the need for level-shifting circuitry.

CA3140 vs. 741 at a glance

Characteristics at Supply Volts: $V+ = 15, V- = -15$ @ 25°C	Limits						Units
	CA 314OT, S			CA741CT,S			
	MIN	TYP	MAX	MIN	TYP	MAX	
Input Resistance, R_I	300,000	1,500,000	—	0.3	2	—	MΩ
Input Current, I_I	—	10	50	—	80,000	500,000	pA
Input Offset Current, I_{IO}	—	0.5	30	—	20,000	200,000	pA
Input Offset Voltage V_{IO}	—	5	15	—	2	6	mV
Slew Rate, SR (Closed Loop)	—	9	—	—	0.5	—	V/μs
Gain-Bandwidth Product f_T	—	4.5	—	—	1.0	—	MHz
Common-Mode Input Range, V_{ICR}	−15	−15.5 to +12.5	+11	−12	±13	+12	V
Output Swing $R_L = 2K\Omega$	−14	−14.4 to +13.0	+12	−10	±13	+10	V
Large Signal Voltage Gain A_{OL} $R_L = 2K\Omega$	—	20,000	—	—	20,000	—	

Versatile building block

Beyond standard op amp uses, the CA3140 can perform in many other applications. Such as ground-referenced single-supply amplifiers. Sample and hold amplifiers. Long-duration timers/multivibrators. Photocurrent instrumentation. Peak detectors. Active filters. Comparators. Tone control circuits. Function generators. Power supplies. Portable instruments. Intrusion alarm systems.

Six commercial versions are available: in the TO-5, the standard CA3140T and the premium types CA3140AT and CA3140BT; the CA3140S, CA3140AS and CA3140BS are the DIL-CAN versions of the TO-5. Also available is the chip version—CA3140H. The CA3140 series is available processed to all levels of MIL-M-38510/883.

Send for 13 useful circuits.

To show you how useful the CA3140 is, we've designed it into 13 typical circuits. To get these circuits plus other information, contact your RCA Solid State distributor. Or RCA.

Write: RCA Solid State. Box 3200, Somerville, N.J. 08876; Ste Anne de Bellevue H9X 3L3, Canada; Sunbury-on-Thames, U.K.; Fuji Bldg., Tokyo, Japan.

RCA. Full house in Linear ICs.

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SIGNALS and NOISE

Letter on IEEE generates "noise"

Dear Editor,
This reply is directed to J. Hemschoot's letter concerning IEEE (June 20th "Signals and Noise").

Mr. Hemschoot:

1. Unless you are a freak, you are one of the many Junior E.E.'s (i.e., less than 10 years in this trade) still suffering from the 4+ years of Ivory-Tower brainwash.
2. Let us hear from you after you have your M.S., your Ph.D., your P.E. license...say, in about eight years when RCA is through with you (up to date and all)....Perhaps at your layoff party, Dr. Hemschoot?

As for now, Mr. Hemschoot, just look around your office—your group (not your boss)! How many are

over 30—?
over 40—?
over 50—?

RCA has been around since 1920, and from 1920 to 1976, your age group (±3 years) represents less than 7% of the E.E.'s graduated in the USA.

How come you only see the young ones like yourself? Where are all the over-40 chaps? Management? Come now, Dull Dillard laid that one to rest (less than 10% of all E.E.'s get into Management!). Would you care to try to beat the odds? ("Up to date" doesn't count nearly so much.) Or will you have to settle for the same fate all your other predecessors got from RCA?

Mr. Hemschoot, next time you need a taxi, a jeweler or a repairman, ask the man: "Are you my future?"

Feerst may be your only hope!

Sincerely,
David M. Weigand, P.E.
West Chester, PA

Dear Editor,
This is in response to your note after J. Hemschoot's letter ("Signals and Noise," June 20, 1976).

You are correct in pointing out that two junior E.E.'s salaries equal one senior E.E.'s salary. But one senior gynecologist's salary/income equals 30 fledgling M.D.'s or 120 interns'. For their sake, don't tell the I.R.S.!!

Sincerely,
Paul Christi
Senior E.E.
IDR Corp.
Farmingdale, NY

Good grief!

Dear Editor:
The EDN news story "Is that really you, Charlie Brown?" (June 20, 1976, pg. 32) leaves the reader with the false impression that the error statistics quoted for the Automatic Handwriting Verifying (AHV) system are the true performance characteristics. The article omits some of the laboratory test results.

Veripen has improved the equipment in the last two years and will deliver a new generation of AHV equipment that incorporates features derived from the conclusions of the MITRE test. The following statement provides more detail on the testing of this equipment:

"The AHV system tested by the Air Force in mid-1975 was the breadboard version of Veripen's Automatic Handwriting System.

"In laboratory tests jointly conducted by Veripen and the Air Force in late 1974 using the breadboard equipment, test results were:

(1) False rejection less than 1%
(2) False acceptance (random) less than 2%
(3) Forgery success less than 2%

"When the AHV system was delivered to the Air Force, many

Zilog products are available now. Contact:

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ARIZONA MESA
Nakoma (602) 834-6549
CALIFORNIA LOS ANGELES
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For more information, Circle No. 16

The Battle of the 80's continues:

With the introduction of Zilog's Z-80 microcomputer products the tide is turning in the battle for supremacy.

Features:	8080A	Z80-CPU	Features:	8080A	Z80-CPU
Power Supplies	+5,−5,+12	+5	Addressing Modes	7	11
Clock	2Φ, +12 Volt	1Φ, 5 Volt	Working Registers	8	17
Standard Clock Speed	500 ns	DC to 400 ns	Static Operation	No	Yes
Interface	Requires 8222, 8228 & 8224	Requires no other logic and includes dynamic RAM Refresh	Non-maskable Interrupt	No	Yes
			Full TTL Compatibility	No	Yes
Interrupt	1 mode	3 modes; up to 6X faster	Throughput	Up to 5 times greater than the 8080A	
Instructions	78	158*	Program Memory	Generally 50% less than the 8080A	
OP Codes	244	696			

*Including all of the 8080A's instructions.

The Z-80 is a third generation LSI component set including CPU and I/O Controllers with full software support and second sourcing available now.

A single chip, N-channel processor arms you with a superset of 158 instructions that include all of the 8080A's 78 instructions with total software compatibility. The new instructions include 1, 4, 8 and 16-bit operations. That means less programming time, less program storage and less end costs. And you get memory-to-memory or memory-to-I/O block transfers, nine types of rotates and shifts, bit manipulation, a legion of addressing modes and a standard instruction speed of 1.6μsec. The Z-80 CPU and peripheral circuits require only a single 5V power supply and a single phase clock. With these circuits you can interface directly to a wide range of both parallel and serial interface peripherals and even dynamic memories without other external logic. With all these features you'll require approximately 50% less memory space for program storage and you'll get up to 500% more throughput than the 8080A.

The Zilog Batallion includes a development system with: Z-80 CPU Card with 4K Bytes of ROM/RAM Monitor software • 16K Bytes of RAM memory, expandable to 60K Bytes • Real Time Debug Module and In-Circuit Emulation Module • Dual Floppy Disc System • Software Package including Z-80 Assembler, Editor, Disc Operating System, File Maintenance and Debug.

We'll support this with resident microcomputer software, time sharing programs, software libraries and high-level languages such as PL/Z.

A reserve of reinforcements is ready. The Zilog Z-80 brings to the battlefront new levels of performance and ease of programming not available in second generation systems. And while all the others busy themselves with overtaking the Z-80, we're busy on the next generation—continuing to demonstrate our pledge to stay a generation ahead.

The Z-80's troops are the specialists who were directly responsible for the development of the most successful first and second generation microprocessors. Nowhere in the field is there a corps of seasoned veterans with such a distinguished record of victory.

Think of your next microcomputer as a weapon against horrendous inefficiencies, outrageous costs and antiquated speeds.

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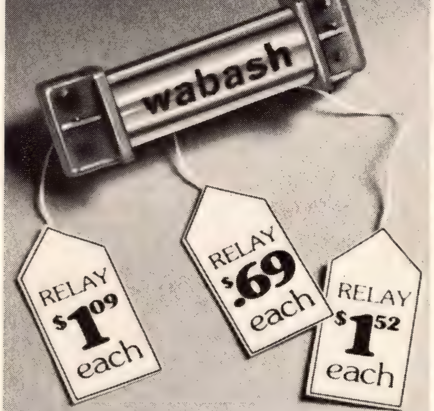
AN AFFILIATE OF EXXON ENTERPRISES INC.

What's the right price for this 1 Form A dry reed relay?



If we told you it has a premium quality switch and precision pins (not bent switch leads) would that help? Or that it's magnetically shielded, U/L listed and meets NARM/EIA proposed standards?

Would it help if we told you it's available in both Form 1A and 2A with .1" and .15" pin spacing, is the most automatically manufactured dry reed relay in the whole world and is available from stock ...from Wabash? The right price? All the prices are right. They're the under 25, 100 or MORE and 25,000 prices respectively.

Hard to believe, but true. And we have many other types available, handsomely priced, to fit your needs and budget. So if you'd like to know more, write us (on your letterhead) for a free sample, or call us for a high volume price quote and let us show you how, at Wabash, the price is always right.

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of the operational procedures were not finalized. Chief among these was the proper procedure for enrollment. MITRE's paper at the Conference illustrates how results can vary widely with operational changes. It shows the effect of less controlled enrollment procedures. When eight signers were re-enrolled, their error rate dropped from 29 errors in 51 attempts to one error in 54 attempts."

Sincerely,
Richard C. McCluskey
Information Specialist
Public Information Division
Hanscom Air Force Base, MA

More scoop on scopes

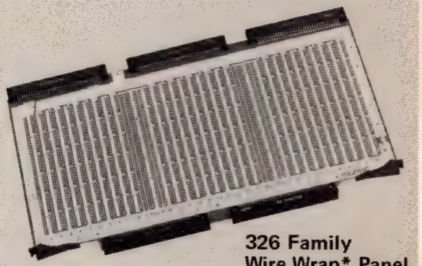
Omitted from Associate Editor Martin Marshall's June 20th rundown on low-cost oscilloscopes was Simpson Electric Co., 853 Dundee Ave., Elgin, IL 60120. Their newest offering, Model 455T, is a 12-MHz, 5-in. scope that features 19 calibrated sweep speeds plus TVH, TVV and VITS; external, internal, line and TV sync; internal sync separator for TV; exclusive gate output for flyback tests; 30-nsec time; and Z-axis modulation. It sells for $395 (an optional 10:1 probe costs $18.40).

New source of supply

"Miles/gallon measurement made easy with CMOS rate multipliers" by Gary Summers of Signetics (EDN, Jan. 20, 1976, pgs. 61-63) proved extremely popular with readers. Therefore, we note that Quest Electronics offers a special components package for this circuit, including a digital flow sensor ($29.50), a speed transducer ($8), CMOS rate multipliers ($19.95) and two 0.50-in. displays ($2.50). Send a 13¢ stamp to: Box 4430C, Santa Clara, CA 95054 for a free catalog.

YOU ASKED FOR IT!!

"The Pluggable-Planar System"



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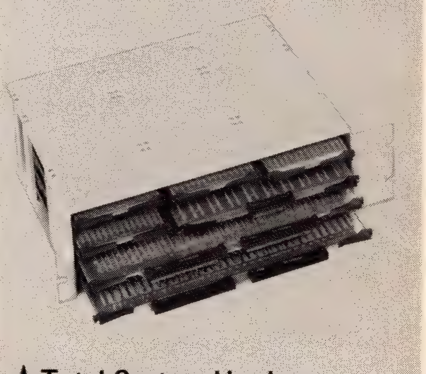

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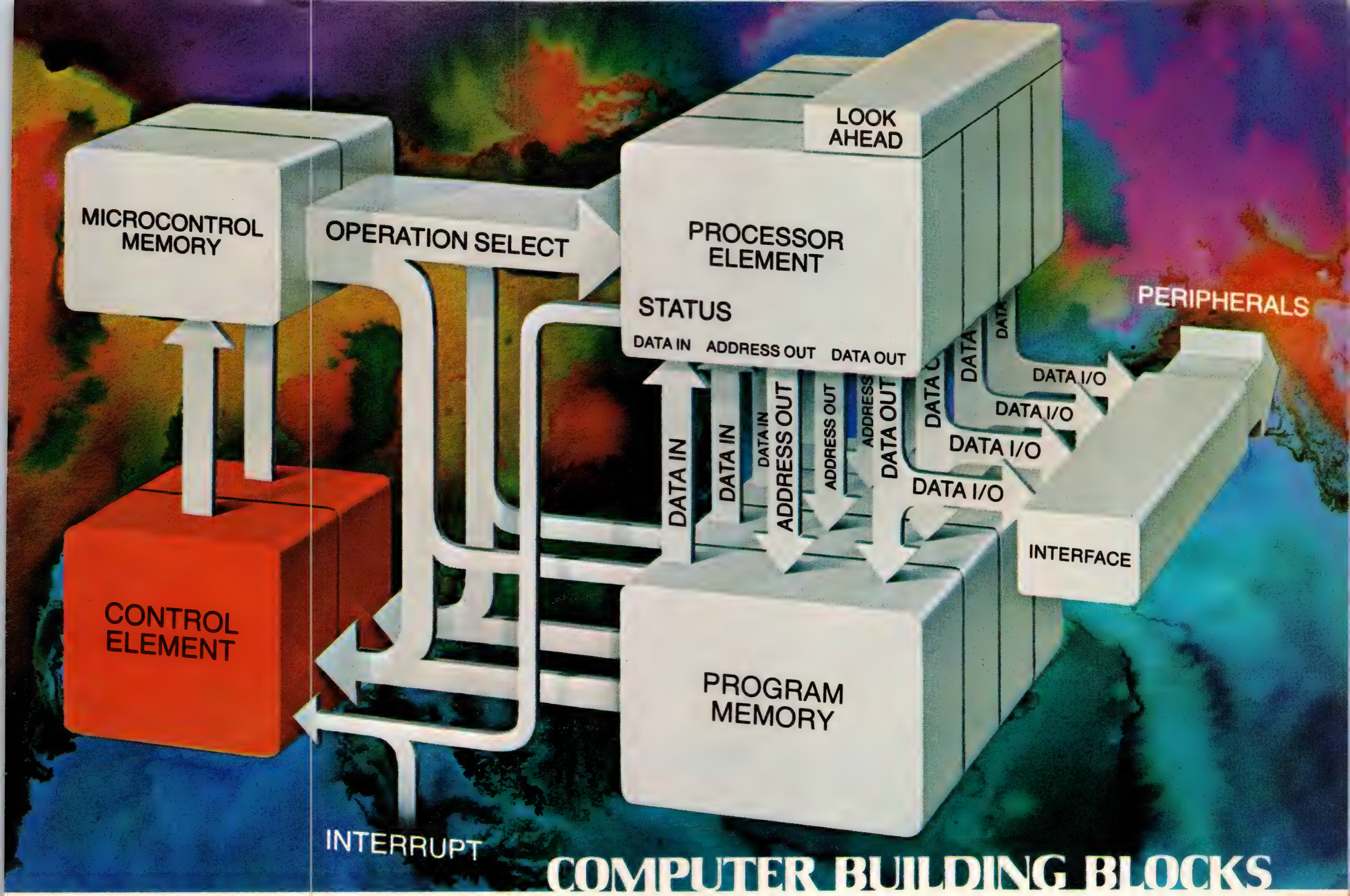
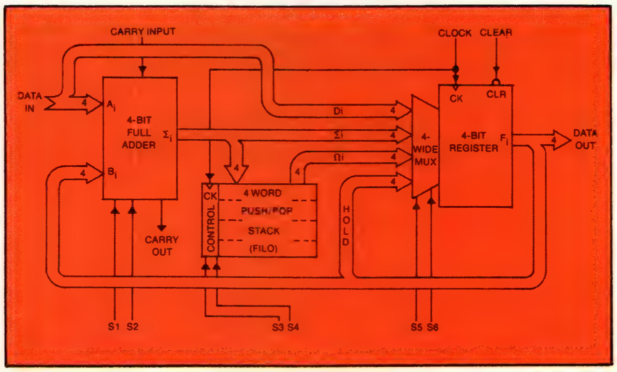


Bipolar building block number one. The control element...SN54S/74S482 Fast. Flexible. Efficient.



TI's new series of bipolar digital building blocks are designed specifically for implementing modularly expandable, high performance computer or controller systems with complete microprogrammability. Build new designs tailored to your applications or emulate existing designs—without loss of software compatibility—and with maximum memory efficiency.

The 'S482 is a key member of this new Series. The highest performance 4-bit-slice Schottky TTL control element available. Use it in any application where bipolar speeds and flexible microprogram control are necessary.

The 'S482 integrates a full adder, four-word push-pop stack, source select multiplexer and address register. All in a space saving 20-pin package. In addition to simple loops and forward sequences, the 'S482 can be used to implement the powerful operations needed to decrement, vector, offset or jump (in a single cycle) to any address within the domain of the controller.

Subroutines can be nested up to four levels deep in the 'S482's push-pop stack and be retrieved in the reverse order of occurrence. Moreover, the stack can be updated without changing the output register's contents.

Use the 'S482 as a powerful next-address generator in a microprogrammed CPU. Or, by itself, as a stand-alone simple controller.

The SN74S482N is priced at $6.30 each in quantities of 100. Available now from your local authorized TI distributor. For a data book describing the 'S482 and TI's full line of bipolar microcomputer components, write to: Texas Instruments Incorporated, P. O. Box 5012, M/S 308, Dallas, Texas 75222.

Features

- Expandable to N-bits in 4-bit increments
- 25ns maximum address load time
- Space saving 20-pin package
- SN74S482N for 0 to 70°C applications
- SN54S482J for −55°C applications

Functions

- Generates forward or backward sequences
- Implements offset, vector, branch or jump
- Stores four return or link addresses
- Direct load to output register
- Holds or initializes system

TEXAS INSTRUMENTS
INCORPORATED

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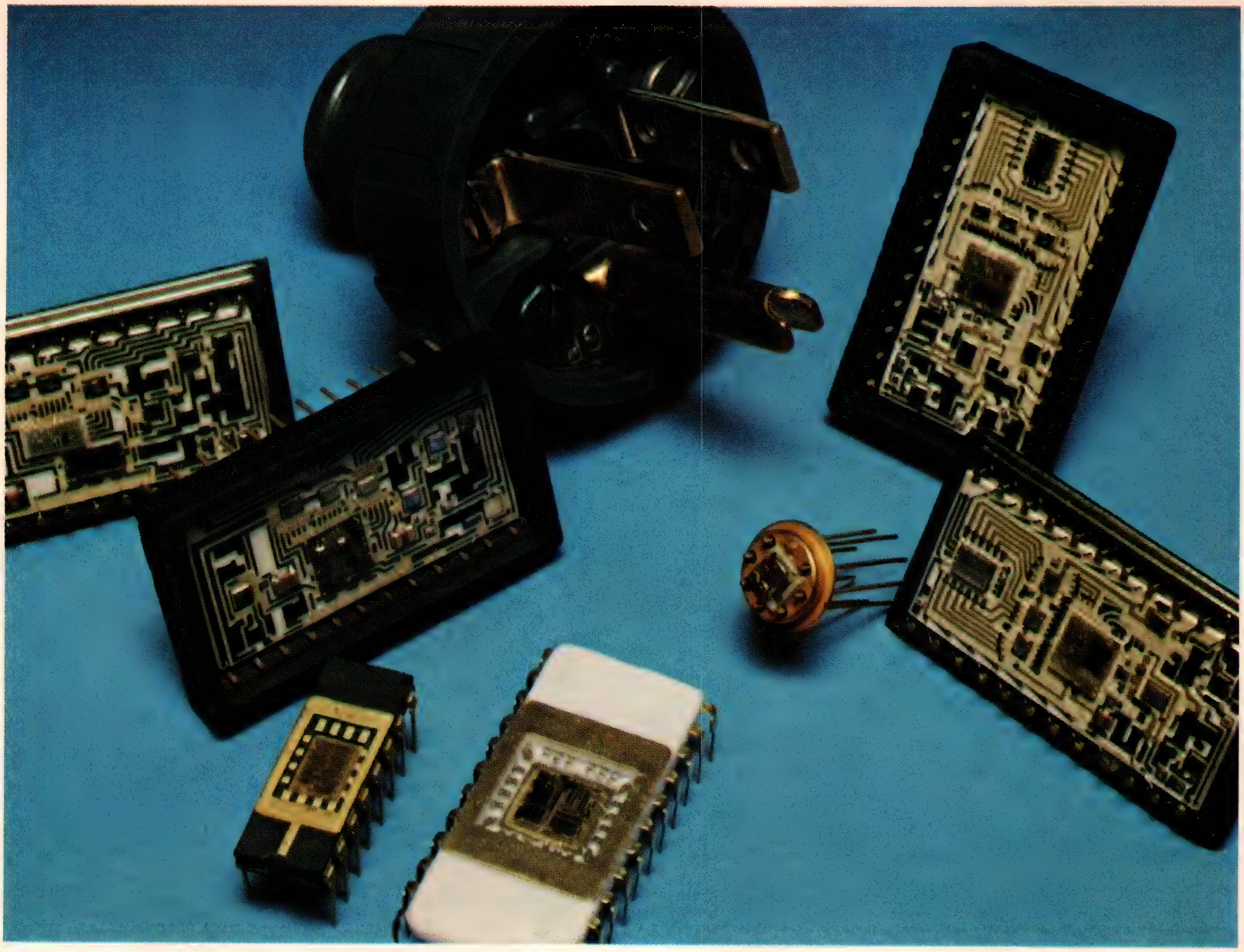

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EDITORIAL

It's all a matter of attitude!

How many times have you left your doctor's office unsure of what illness you have or don't have? No matter how many questions you ask, the answers are just indefinite or vague enough so that you think you understand—until you try to explain it to someone else! I was beginning to think there must be a course in med school entitled "How to talk down to your patients because they aren't smart enough to understand anyhow."

This impression was recently shattered, however, when a young doctor sat me down after an examination and told me what was wrong (and not wrong) in a clear, definitive, understandable manner. He answered my questions likewise. I've since had similar experiences with other doctors, and believe me, it's refreshing.

So how does this relate to electronics? Very simply: It's the attitude that matters. Electronics, because of natural evolutionary developments and especially the microprocessor, is moving into many previously nonelectronic markets, industrial and consumer as well. We will therefore have to explain our technology, products and systems to people completely unversed in the subject we know so well.

How are you going to handle that situation? Are you going to explain things in the same manner that you'd present a paper at a technical conference or write an article for EDN? Are you going to talk down to these people because they're "not smart enough" to understand? I hope not!

The people you'll be dealing with are intelligent and expert in their own field. So why not explain your electronics wizardry in terms they'll understand and feel comfortable with? Use analogies, mechanical or hydraulic equivalents, or whatever. Keep it clear, definitive and comprehensible, but don't be condescending. It's challenging and can be fun. After all, the world of electronics really isn't as mysterious as some make it out to be.

Roy W. Forsberg

Editorial Director

Now, a single integrated circuit, our TAD-32 (Tapped Analog Delay), can provide filtering with passband-to-stopband ratios of 40 DB or more per device. Simple variation of the clock sampling rates over 5 decades will accordingly shift a given filter characteristic. Transversal or recursive filters can be constructed with over 60DB dynamic range and linear phase. Tapped delays up to several hundred milliseconds are possible.

Discrete time analog signal processing using charge transfer devices is a reality at RETICON.

The TAD-32 is just one device in this growing family.

We don't just talk about them, we make them.

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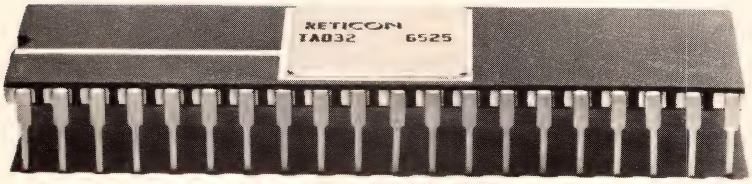

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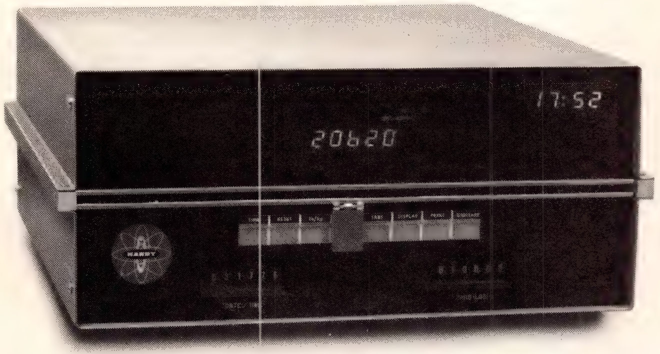
They created new system capabilities with Motorola's M6800

OHIO-NUCLEAR, INC.

In Nuclear Medicine, scintillation cameras produce images of heart, lungs, even the entire body. Event-by-event image uniformity is essential to assure the physician that irregularity means disease, not instrument variation. Motorola's M6800 Family generates the necessary uniformity and reduces service call frequency through continual uniformity analysis and regulation in Ohio-Nuclear's 200,000 gamma events-per-second Sigma 410 Radioisotope Camera.



HARDY SCALES

The Model 2070 is a programmable, self-contained, data-oriented, NBS compatible industrial weighing system priced under $3,000. It has the full range of standard features and a selection of sophisticated optional expansion capabilities. It provides display, drives printers, and interfaces with computers and process controllers. Motorola's MC6800 is the heart of the system.

KRAUS INDUSTRIES, LTD.

MICRO-1P, designed around the microprocessor, introduced a totally new concept in data and control systems for self-service gas stations. Most of its standard features for complete station control were previously available only as options, or not at all. Kraus Industries credits Motorola's M6800 Family for this advanced system, and for keeping it price competitive.

Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036

MOTOROLA Semiconductors

—and you thought we were just a production house

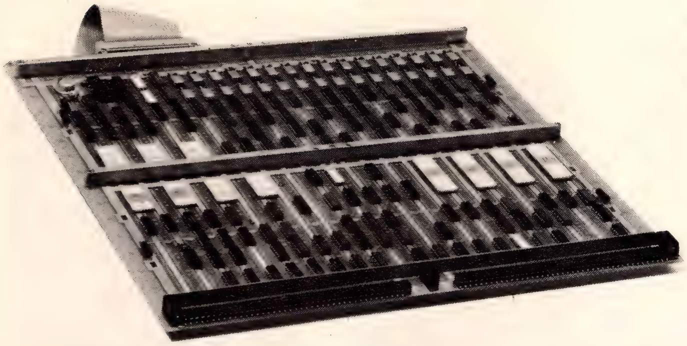
Interdata presents the first OEM Minicomputer Buyer's Guide in Memory.

If you're an OEM in the market for minicomputers, we say let memory be your guide.

Interdata memory that is. Especially if you're interested in high performance, low-cost production hardware and software—in configurations that exactly fit your needs. You can have it all plus superior Interdata architecture, construction, and reliability. And minicomputer technology that gives you the competitive edge, no matter what quantity you buy.

Here's how to take advantage of these benefits:

For 8KB to 16KB remember the Interdata 5/16.



When you select the 5/16, you get the CPU built for high-volume OEM buyers, who want the best of both the minicomputer and microprocessor worlds.

With the 5/16, you get a complete Interdata computer with MOS main memory on a single board. It includes a full 16-bit processor with 16 general purpose registers, 114 instructions. 8KB of NMOS dynamic random access memory expandable up to 64KB. And a memory cycle time of 600 nanoseconds. You also get minicomputer performance and upward compatibility to the complete Interdata family of 16- and 32-bit minicomputers with our standard Multiplexor Bus.

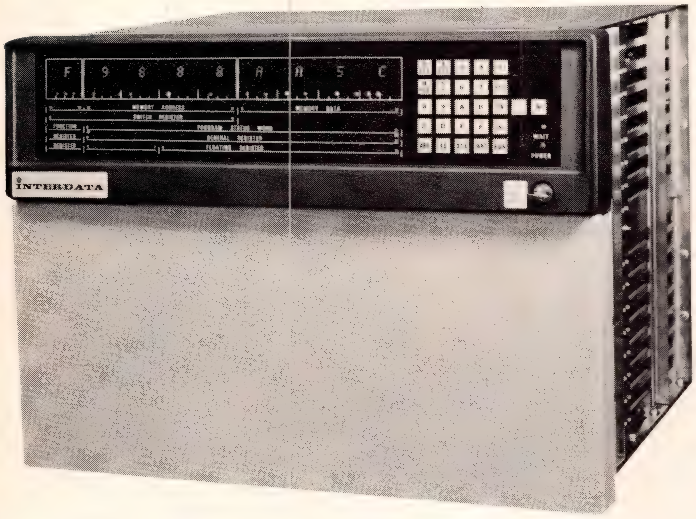
The 5/16, Interdata's lowest cost processor, bridges the gap between the mini and the micro with its unique new Micro Bus which helps system designers maximize performance while minimizing total system cost.

For 16KB to 32KB remember the Interdata 6/16.

With the 6/16, you get either 600 nanosecond MOS memory or 1000 nanosecond core memory. Plus superior Interdata construction and ruggedness. And unmatched performance in its price range.

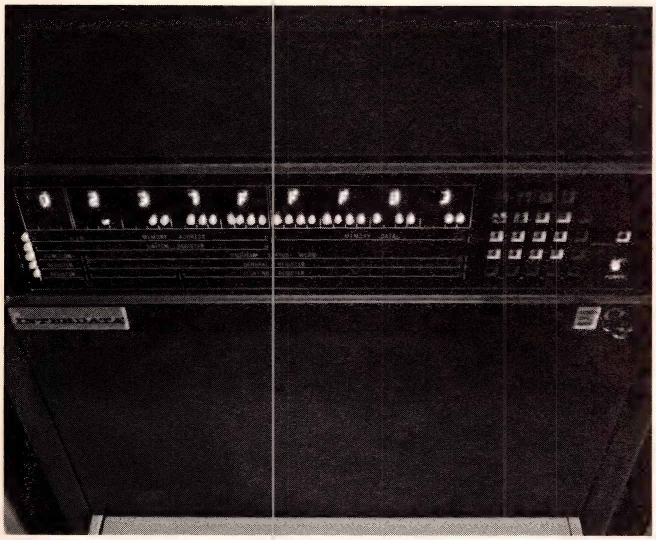
The Model 6/16 accepts all Interdata high- and low-speed peripherals and is available either in an economic package, or in a low cost board set.

For 32KB to 64KB remember the Interdata 8/16.



When you select the 8/16, you get the highest performance member of Interdata's 16-bit OEM product line. Perfect for the user who needs high performance capabilities, the 8/16 gives you register-to-register instructions in 750 nanoseconds and special instructions for real-time applications. And, it's available in low-cost packages with popular options such as single and double precision floating point hardware.

For 64KB to 1 Megabyte remember the Interdata 7/32 and 8/32.



If you're an OEM interested in large memory, you should consider Interdata's 32-bit line of minicomputers.

Our 7/32 is an economical machine with a directly addressable main memory expandable up to a million bytes of 750 nanosecond core. It performs either 16-bit or 32-bit arithmetic and logical manipulations.

The Interdata 8/32 Megamini™ offers you an unequalled combination of power, flexibility and reliability in a compact package. It includes direct addressing to one million bytes. Full 32-bit hardware with performance enhancers such as dual instruction look-ahead stacks. Multiple register sets. Writable control store. Interleaved 32-bit memory. And fast, floating point hardware. The 8/32 delivers performance characteristics you'll find only on large scale, more costly computers.

For OEM minicomputers remember Interdata.

Even before you decide on a minicomputer, let Interdata field sales engineers and systems analysts help you plan your computer-based product. Our ready-to-use, packaged development systems are designed to help you get your product to market early. The entire Interdata family of hardware products includes a broad range of peripherals ideally suited for the OEM. In addition, Interdata offers a family of software products designed to deliver a dynamically balanced framework for running your application programs.

Remember, with Interdata you get high performance, low-cost production hardware and software—in quantity configurations that exactly suit your requirements. And it's all backed by Interdata's unique Computer Life Support program. Send for more information about Interdata's OEM Minicomputers. Or call us. When you remember Interdata, we remember you.

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It's a well-known fact from the east coast to the west coast that the Corning boys can out-ride anything in sight.

Any day of the week, you can hear Ol' Whip Resistor regaling youngsters like The Minitan Kid with tales of Corning's legendary speed, even during The Great Resistor and Capacitor Pinch of '74.

There's a glint of steel in the resistor's eye as he leans close to Minitan and says: "You know, Kid, you don't get your spurs just by being good. You gotta be fast, too." Whip leans closer. "Our customers expect us to be good and they expect us to be fast. *And Kid . . . we are . . . always.*"

You could hear a pin drop in the Bar-C bunkhouse. Then Ol' Whip cracks a toothy grin and slaps Minitan on the back.

What the boys don't always talk about is

COMPONENT HISTORY

what makes them so fast on the draw. We back up our distributors' extensive inventories with a huge, separate, off-the-shelf stock. If a Corning distributor runs short of something you need, it's shipped pronto from our Corning distributor warehouse.

At Corning, "fast" is carved in stone right alongside "good". So when you need Corning metal film resistors, glass and ceramic capacitors and miniature tantalum capacitors and you need 'em fast, you get 'em fast.

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ANNOUNCING

a totally new line of high performance, low-cost digital panel meters

Large, bright, easy-to-read LED display
High reliability LSI design

New from Weston. The 2460 Series digital panel meters. An innovative line of meters that combines the best in semiconductor and display technology for all 3½ digit applications. The result is better performance, better reliability, and better price. In fact, you can now get the best in Weston DPM performance at a price of only $80.*

The unique Weston two-chip LSI circuit design in the 2460 Series reduces the number of components. This provides added reliability and helps to cut cost. And Weston has done it without sacrificing the outstanding characteristics of its patented Dual Slope Conversion** method of circuit design for long term stability—an industry acknowledged superior method.

This LSI feature alone makes the 2460 Series a good buy. But Weston took it one step further. We replaced the gas discharge display with an LED display. Better reliability. And—our LED happens to be a big and bright 0.6″.

This is the basic story on the new 2460 line of Weston high reliability/low price meters. The rest of it is basic to Weston quality and performance. Single ended or balanced differential input—completely floating, with isolated systems interface. Industry standard pin connections to assure multiple sourcing and simple retrofit requirements. All of these outstanding features are packaged in the popular and industry standard Weston DPM case, requiring only seven square inches of panel space.

The 2460 Series is available in six models that include both AC line and DC powered units.

Ask your distributor for a look at the 2460 Series. It will improve your equipment's performance and reliability while it saves you money. Or, write direct to Weston for additional information.
Weston Instruments, Inc., 614 Frelinghuysen Ave., Newark, NJ 07114

Canada: 1480 Dundas Highway, Mississauga, Ontario
Europe: Ingolstadter Str. 67a 8 Munchen 46, W. Germany

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*In Continental U.S. in O.E.M. Quantities

**U.S. Pat. #3,051,939

Lightwave communications—a system for high-density data transmission

Nearly 50,000 telephone calls carried through a cable only a half-inch in diameter—this is the potential of a new communications system that uses tiny lasers to transmit calls over cables of hair-thin glass fibers. Presently being evaluated in a simulated field environment at Western Electric's facility in Atlanta, GA, the prototype system is yielding valuable information that will help prepare this new technology for final design, manufacture and installation.

You start at the source

Specially developed GaAlAs lasers are used as the light source in the experiment. These lasers send IR light signals into the fiber cables (lightguides) at a wavelength of 0.82 microns at an average power output of 500 μW. Room temperature lifetime for the lasers, supported by measurements at elevated temperatures, is predicted to be greater than 100,000 hours.

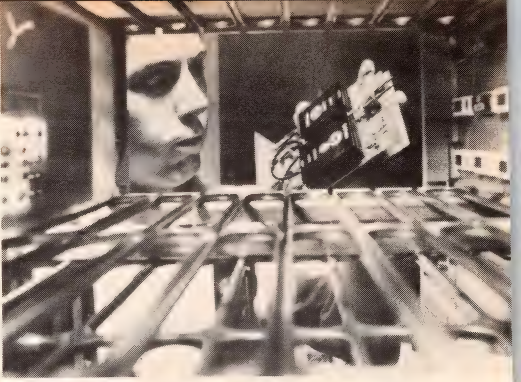
Each laser is part of a transmitter module that includes a modulator circuit which provides 44.7M bits of information per second. The module also includes a feedback circuit that compensates for the effects of temperature variations normally encountered in telephone company use.

Pilot production line for making fiber lightguides is already in operation at Western Electric's Atlanta facility. High-silica-content glass rods are prepared on a glass lathe (glowing area in **upper right**), softened (**upper left**) and then pulled into hair-thin fiber lightguides by equipment shown in foreground.

Status of splice of light is checked by technician in manhole adjacent to laboratory facility. This splicing technique is one of several being evaluated for possible future field use. Cable emerges from duct into manhole, is spliced, and then looped back into the duct for termination inside the lab.

Then go down the cable

The fiber lightguides, made of low-loss silica glass containing controlled amounts of other



The modular design, which leads to easy installation and handling, is evident on the transmitter circuit board being removed from equipment bay. Laser light source is in the lower black box and all its control circuitry is in the upper box.

oxides, are a versatile multimode graded-index type that can be used with either a laser or LED light source. Coated to protect against humidity, abrasion and losses due to bending, the lightguides are formed into flat color-coded ribbons. A dozen of these ribbons (each containing 12 fibers) are enclosed in a cable that minimizes transmission losses and cushions and protects individual fibers against damage in field use.

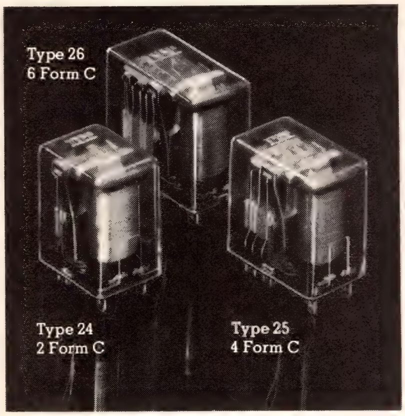
Average signal loss in the fibers (measured after cabling and installation in ducts) is 6 dB/km (10 dB/mi.). This figure indicates that the light pulses could be transmitted 7 km (about 4 mi.) before regeneration is required.

At the receiving end of the cable, a silicon avalanche photodetector converts the light signals to electrical signals. This detector is part of a receiver module that also contains the circuitry necessary to process the signals for transmission through a nationwide network.

It's far more than a theory

Test results indicate that the system could go on-line today. Initial applications would likely involve the transmission of digital information between metropolitan-area switching centers. Underground-cable duct space is already limited in such areas, and digital transmission is already used quite extensively. Most importantly, distances between adjacent switching centers is usually less than four miles. Lightwave communications systems will not require any repeaters in such applications.

Ultimately, the lightwave system may be used throughout the entire telecommunications network. Since lightguides are not affected by electrical interference, lightwave systems offer a big plus factor for carrying large quantities of data over short distances in "noisy" environments. Bringing new types of visual communications services into business locations, as well as private residences, is still another possibility of this new technology.—*TO*



If you can't say "yes" to all these questions, you're not getting your money's worth from your R10, W67, AZ420, 62, V230-type relays.

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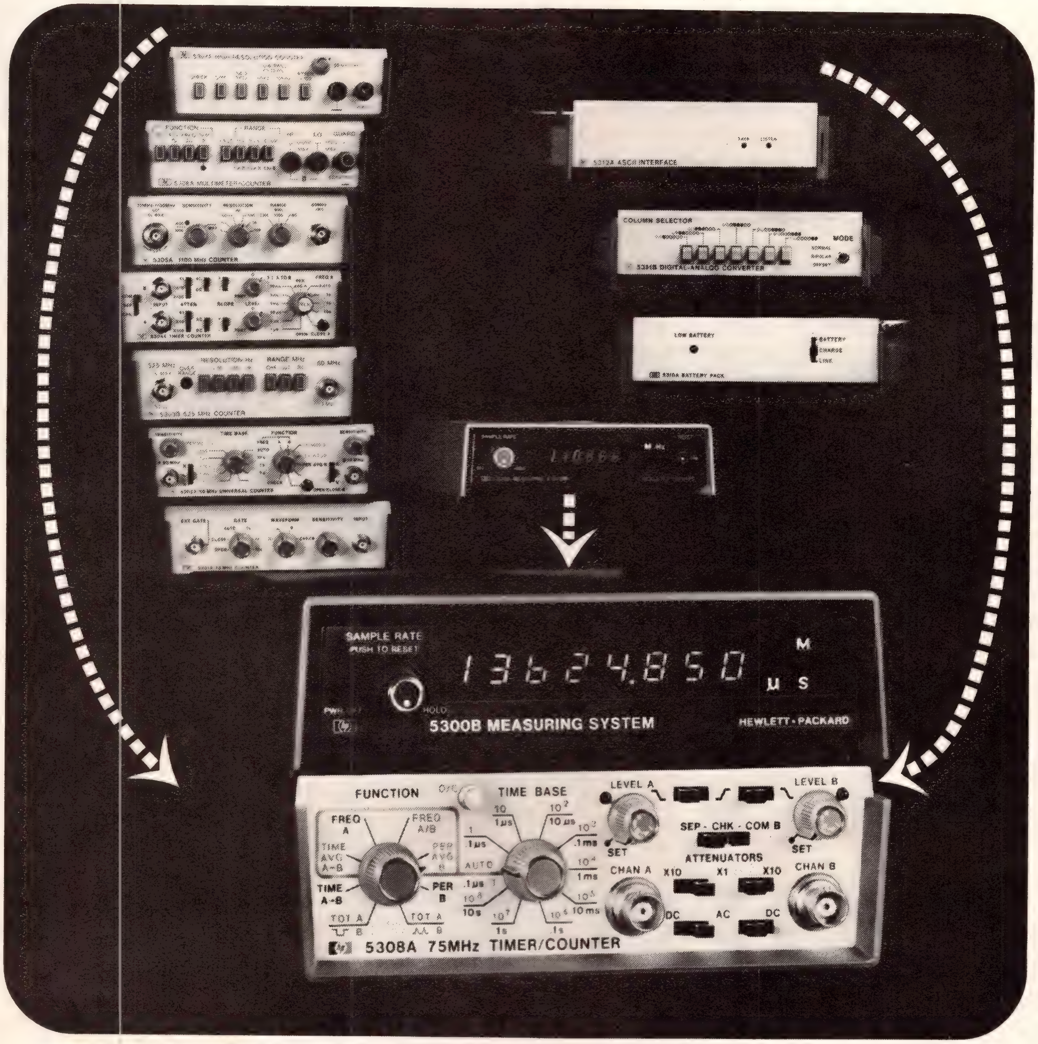

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For more information, Circle No. 25

Computers fall in step and join the exodus from inner-city to suburbia

Traffic-control computer systems have been employed for many years, but for the most part only in cities. Now, for the first time, computerized traffic control has been implemented on a supraregional level—in the Rhine-Main highway network of the Frankfurt, Germany area.

A Siemens traffic-control computer is the heart of this trial system. The unit interprets traffic-volume data and, when it finds certain highway sections carrying unequal volume, operates variable relief-route signs at highway interchanges. By heeding the signs' advice, motorists can bypass overloaded highway sections and avoid congestions, loss of time and accidents.

Simple yet sophisticated

Essentially, the computerized system consists of four components or subsystems—variable relief-route signs posted at highway interchanges, detectors for real-time traffic-data collection, a transmission system and a control center with a Model 16030 computer.

The detectors, embedded in the roadway surface, send a significant amount of information back to the control center. In addition to vehicle volume and speed data, they also differentiate passenger cars from trucks. This vehicle discrimination is important in those

Computerized traffic control on a supraregional level is being realized for the first time in a trial system set up on highways between Frankfurt, Weisbaden and Darmstadt, Germany. The photo shows a variable relief-route sign being changed by the central computer.

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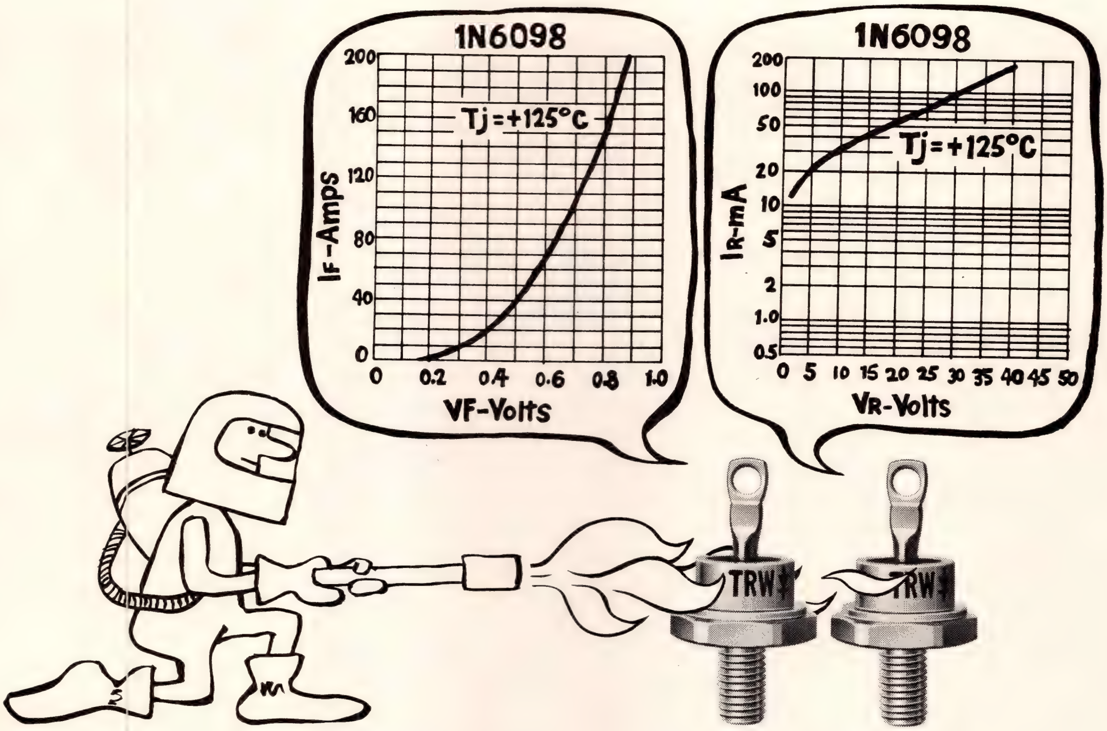

These new TRW Power Schottkys have quite a story to tell and it starts with the fact that they're JEDEC registered. Then they'll tell you that they let you maintain 50 Amps—typically 0.55 Volt forward drop at a T_j of 125° C. The highest operating junction temperatures, lowest reverse leakage typically less than 200mA @ 40V, 125° C, and highest voltages on the market today. (Yet, for all that, they're competitively priced.)

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cases where traffic must be diverted onto routes with uphill gradients.

Back in the control center, the received traffic data is processed and displayed (in a consolidated form) on both a video display and a mimic diagram. When these indicators show sections of a highway carrying excessive traffic volume, a traffic-rerouting program, which controls the variable relief-route signs, begins operation.

Along the highway, the route signs are located in groups of three—two advance and one main sign. Signs within a set change consecutively, rather than simultaneously, at a rate determined by the average vehicle speed prevailing on the respective highway section. This procedure minimizes the number of motorists that might receive contradictory rerouting recommendations.

Current traffic situation is shown on a wall-size mimic diagram located in the system-control center. This diagram also indicates the current status of various relief-route signs installed at several highway interchanges.

Humans still in the loop

Since this trial system is breaking new ground in the field of traffic-control engineering, much remains to be learned. System performance, though promising, is not fully automatic yet. For example, the computer does not presently have direct control of roadside signs: It outputs data relevant to the rerouting decision and then waits until an operator examines and approves the decision before it changes those signs. When sufficient knowledge is available concerning this traffic-control philosophy, the system will be converted to fully automatic operation.—*TO*

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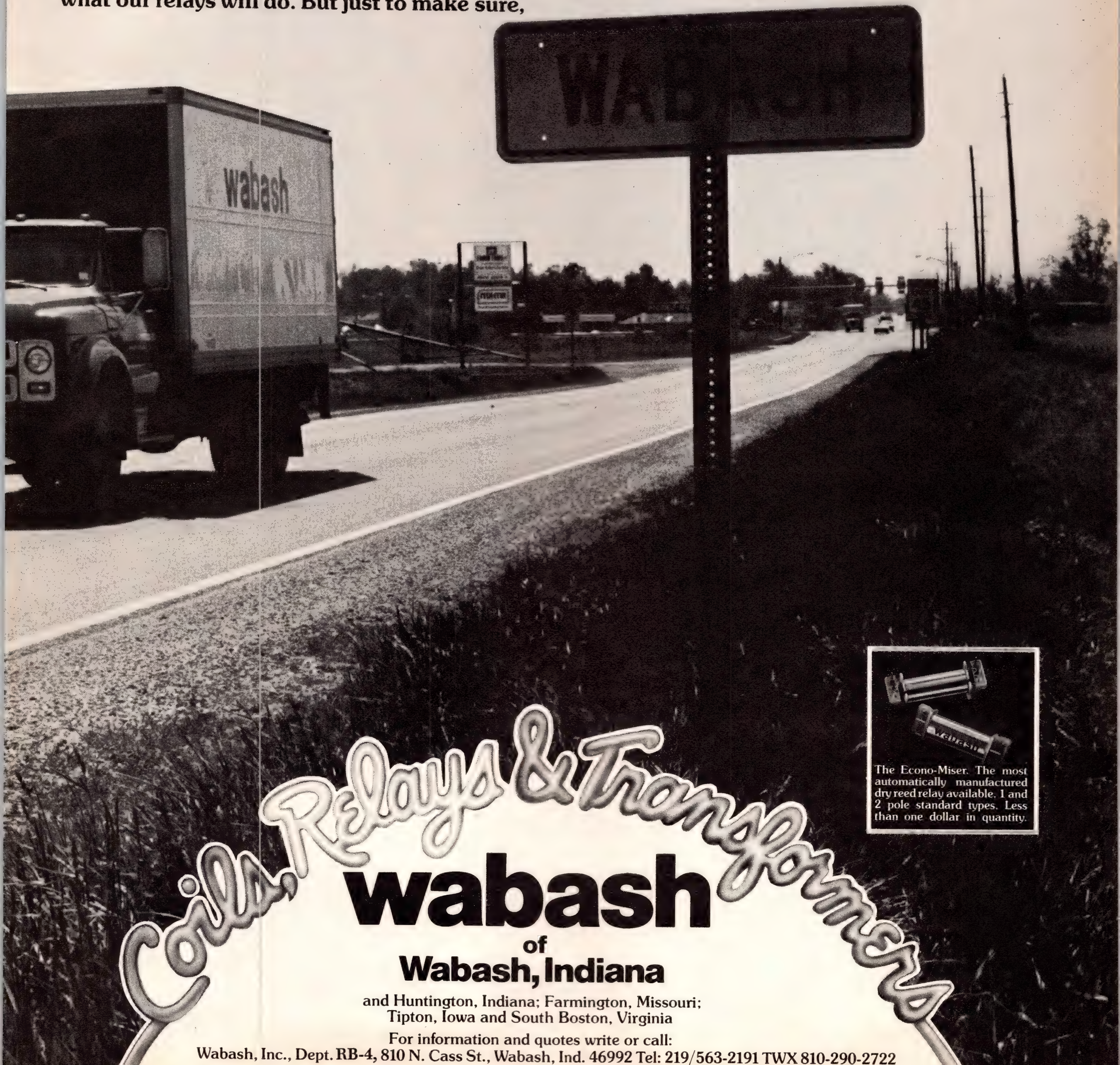

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Automate your instruments.

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The new HP 9815 and HP 9825 computing controllers make interfacing practical and inexpensive. If you haven't automated your instruments yet, hook them up to one of these HP controllers and upgrade your system's performance. You'll get results and reports faster and easier. Increase your system's throughput. Control variables in real-time. Free yourself from manual readings, adjustments, and calculations.

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You can choose from the commonly used interfaces—BCD, bit-parallel/byte-serial, RS-232C, or HP-IB (the interface bus that conforms to IEEE Standard 488-1975). You simply connect your instrument or black box to the cable of the appropriate HP interface card and plug the card into the controller. Then, using simple high-level commands, you program the computing controller to monitor and control your instruments and analyze the data. You don't have to hire a computer programmer to set up and use an automated instrumentation system. That's the friendly, direct approach to interfacing.

The HP 9825: unexpected power for systems control

Though the 9825 retains the friendliness and programming simplicity of a calculator, it has the power and performance of a minicomputer. Features like vectored priority interrupt, buffered I/O, live keyboard, and direct memory access allow it to do several interfacing jobs simultaneously: transferring data and commands, accepting inputs, analyzing data and printing or plotting results. And the 9825 can run application programs and solve keyboard calculations at the same time. Using HP-IB, it can control as many as 42 instruments and peripherals at once. That's big system performance.

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The 9815 at a base price of \$2,900* (I/O option and interface cards/cables extra), is the inexpensive alternative to manual monitoring of an instrument or small system. It can even run control applications unattended. And it can handle a variety of sophisticated compuations as well. Truly, the 9815 provides a lot of performance for the price.

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Electronic Component

Leadtime Index

SEPTEMBER 1976

PRODUCT	LEADTIME IN WEEKS Min.	Max.	Trend
CAPACITORS			
Ceramic	4	11	▼
Electrolytic			
aluminum	5	10	▲
tantalum	4	9	▼
Film			
metal case	5	10	▲
non-metal case	4	11	▲
Mica	3	9	▲
Paper	3	7	▲
Trimming	4	9	▲
CONNECTORS			
Coaxial	4	9	▲
Multipin circular			
high-density	5	12	▲
standard	4	8	▲
Printed circuit	4	8	▲
Rack & panel	4	9	▼
FANS & BLOWERS	5	10	▲
FRACTIONAL H.P. MOTORS	8	19	▲
INTEGRATED CIRCUITS			
DTL	3	8	=
ECL	5	8	▼
TTL	3	9	▲
MOS	3	8	▲
CMOS	4	11	▲
Op amps (monolithic)	3	8	▲
Voltage regulators	4	8	▲
LIGHT-EMITTING DIODES	2	6	▼
MEMORY ICs			
Bipolar	4	8	▲
CCDs	5	9	▲
MOS	3	8	=
MICROPROCESSORS			
Bipolar	4	8	=
MOS	3	6	▼
PACKAGED CIRCUITS			
A/D converters	5	10	▲
D/A converters	5	10	▲
Instrumentation amps	5	11	▲
Sample/hold amps	5	11	▲

PRODUCT	LEADTIME IN WEEKS Min.	Max.	Trend
PANEL METERS	6	10	▲
PRINTED CIRCUITS			
Multilayer	4	7	▼
Two-sided	4	6	▼
READOUTS & DISPLAYS	4	11	▼
RELAYS			
Crystal can	3	8	▲
General purpose	3	7	▼
Reed	3	8	▲
Solid-state	3	8	▲
Stepping	3	8	▼
Telephone	3	9	▲
RESISTORS, FIXED			
Composition	3	6	▼
Dep. carbon & carbon-film	3	7	▲
Metal-film	2	7	▼
Networks	4	8	▼
Wirewound	3	9	▲
RESISTORS, VARIABLE			
Non-wirewound			
non-precision	3	8	▼
precision	3	8	▼
trimmers	3	8	▲
Wirewound			
non-precision	3	8	▲
precision	3	8	▼
trimmers	3	8	▼
SEMICONDUCTORS			
FETs	3	7	▲
Power rectifiers	3	7	▲
Power transistors	3	7	▲
SCRs & triacs	4	7	▲
Silicon switching transistors	3	7	=
Switching diodes	3	7	=
Zeners	3	7	▲
SWITCHES			
Dual in-line	3	8	=
Lighted pushbutton	4	10	▲
Pushbutton	3	7	▼
Rotary	3	9	▲
Snap action	3	7	▼
WIRE & CABLE	3	8	▲

Leadtimes are based on recent figures supplied by a select group of Electronic Business magazine's readers. The figures are averages and represent the time necessary to allocate manufacturing capacity to build and ship a medium-sized order for a moderately popular item.

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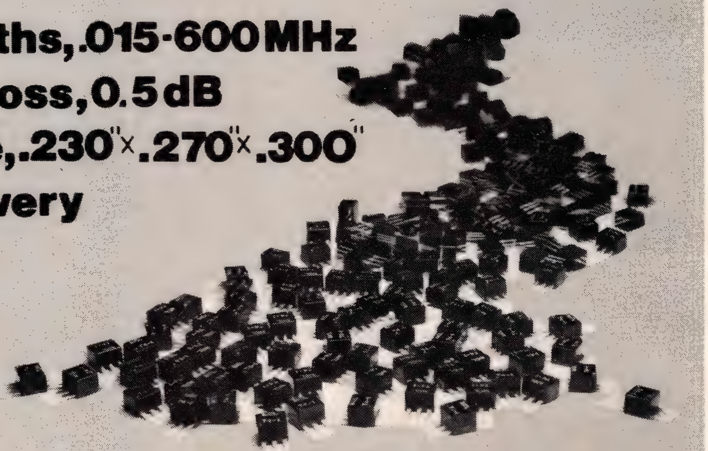

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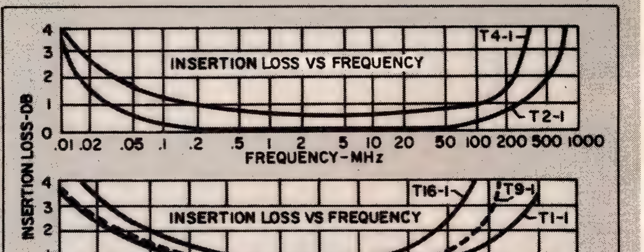
	3db loss	.15-400	.015-600	.2-350	.15-200	.3-120
Price	(10-49)	$2.95	$3.45	$2.95	$3.45	$3.95



For complete specs, performance curves and drawings, see pgs 192-193 of the 1976-77 MicroWaves Product Data Directory.

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Microprocessor provides one-button liquid-scintillation counting

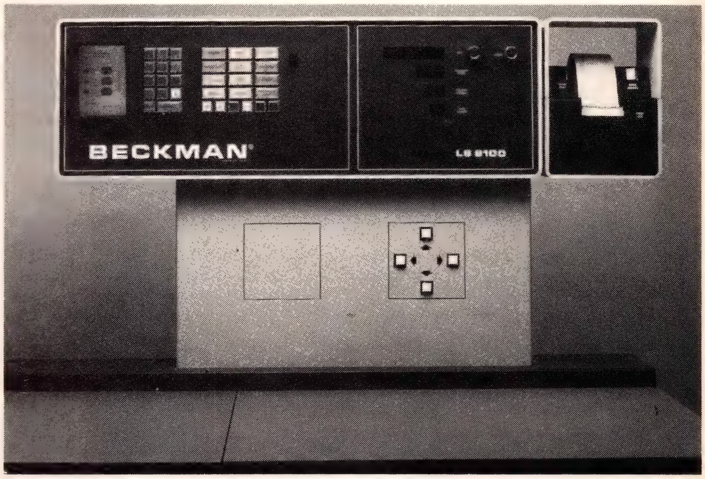
"A key advantage of using a microprocessor in a scientific instrument is the operator interaction it allows. Being able to communicate with the unit keeps the user from thinking it's a magic box and hard to understand." So notes Whitney A McFarlin, engineering manager of the Scientific Instruments Div. of Beckman Instruments. This division is now shipping its first microprocessor instruments, the Series 8000 liquid-scintillation system.

Catching villainous vintners

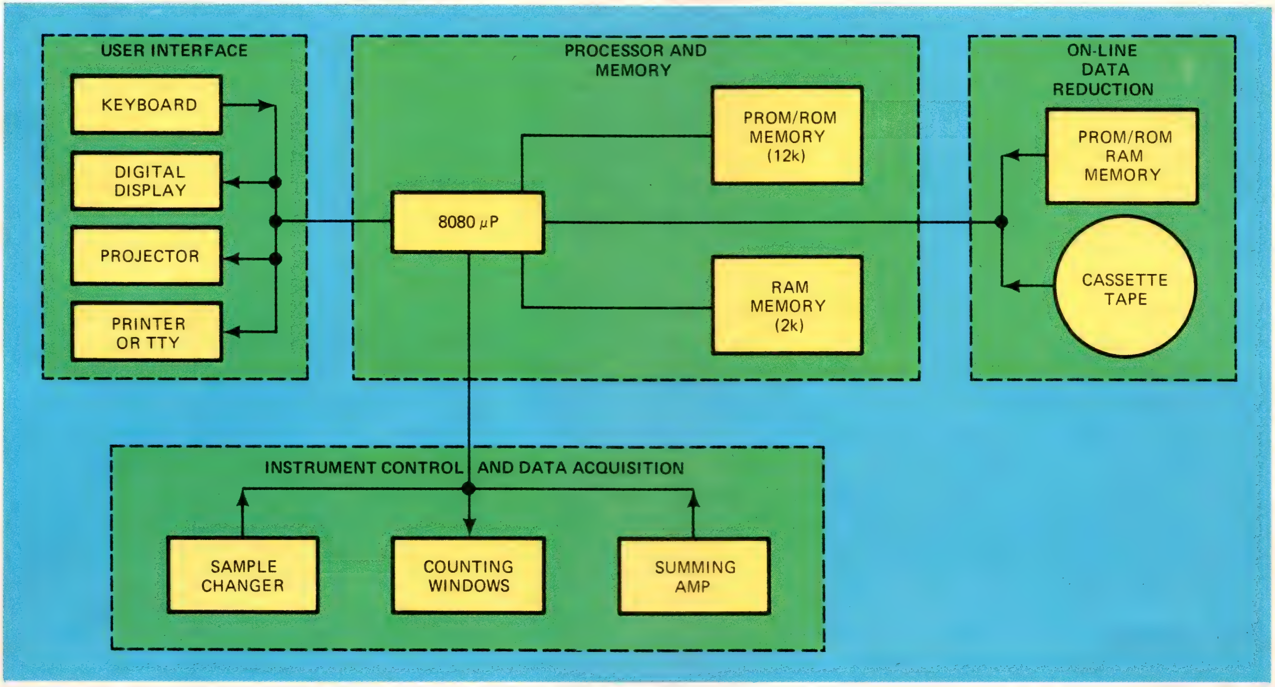
Liquid-scintillation counters are used by biochemists to label biologically interesting radioactive tags, especially tritium and carbon 14, that occur in organic compounds. Typical applications include cancer research, carbon dating and criminology. Liquid-scintillation counting is also used to detect winemakers who lie about the age of their wine: French government scientists track the radioactivity of atmospheric water (dependent on nuclear testing) and, since a year's rainfall provides a major component of wine, thus determine in what year the wine was made.

One-button answer machine

Whether searching for cancer cures, crooks or cavemen, the user of the new Beckman LS system finds his job easy. He simply inserts a sample in the chamber, enters an identification number,



Beckman liquid-scintillation counting system uses a μP for simple operation. Prompting instructions to the user are presented in an easy-to-follow slide display being patented by Beckman.



Basic scintillation system is controlled by the Intel 8080 microprocessor. On-line data reduction is an optional feature that requires extra semiconductor and cassette memory.

and the machine tells him what to do next by activating an innovative slide-projector prompting display. A decimal keyboard plus labelled push buttons are then used to enter requested parameters.

This form of data entry and display is relatively inexpensive and much simpler to use than the traditional teletypewriter or a vast array of push buttons, yet gives substantial information in a schematic form. The slide projector operates from a stepper motor driven by the μP.

The Beckman microprocessor system also includes 10 prewritten programs that can be called up either by the keyboard or a mechanical selector placed in the sample chamber; the user can even hide all switches except "automatic count" under a panel for one-button operation.

Complications are optional

If desired, counting programs can be edited from the keyboard, but the originals stay in memory. A separate TTY or Texas Instruments Silent 700 terminal can also be used for programming. A calculator-type digital printer provides the usual hard-copy output, with analog gas-discharge or digital display depending on the model. A cassette drive is needed for the full computing system.

Designers of this system opted for the Intel 8080; they had earlier worked with the 8008, even writing an assembler since the Intel MDS system didn't exist at the time. Now they use an Intellec 80 for preliminary debugging and burn-in.

For servicing their Series 8000 LS system, Beckman has developed a test-control box that plugs into the motherboard, thus providing their microprocessor instruments with an equivalent of the familiar Intellec 80 panel. The system also has built-in diagnostic programs that automatically check out the unit when power is turned on or the auto-count button is pushed. There is even a single push button that automatically calibrates the entire system.

Finally, in true μP fashion, users can interrupt any sample batch during counting and perform virtually any desired task. After the interruption, the Series 8000 will automatically return to the sample that was interrupted and continue counting. This group is obviously sold on microprocessors and has a number of other μP projects in the works. □

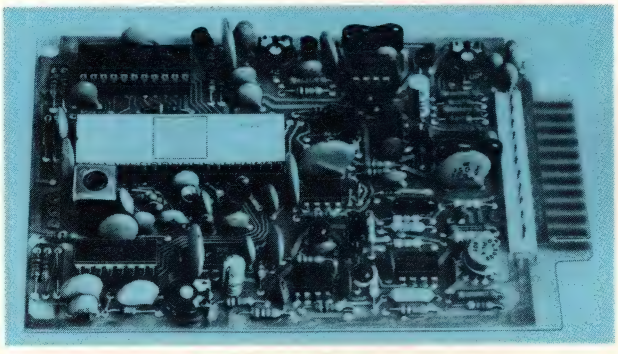
Custom μP eliminates pitch distortion when changing playback speed

What happens when a taped voice plays back at twice its recorded speed? Ordinarily, the voice sounds like Donald Duck huffing and puffing in a real panic. But Lexicon, Inc. of Waltham, MA has developed a patented technique that uses a custom microprocessor to drop Donald's pitch to normal even though the recording still plays at double its original speed.

Available on a 3.5×5-in. pc board, the Varispeech Model 20 pitch shifter and speech compressor/expander is the first device that can perform this function electronically in real time, without pitch distortion or loss of speaker identity. Some applications of this module are obvious—one can speed up the tape of a dull lecture or slow down the recording of a detailed technical discussion. Other applications are limited only by the imagination of the OEM.

Systems in development include one that corrects "helium-speech" in a deep-sea diving bell, while another, originated by the FAA, slows down the panic-garbled speech sometimes found on aircraft flight recorders.

Many applications use pre-recorded data, often a tape-recorded voice. The user controls the speed of the tape transport and thus determines the sampling rate—a faster tape input means more data must be sampled. A sample/hold retains the data until the DAC (multiplexed for both input and output) is available to digitize the input. After using a successive-approximation routine hardwired in the μP, a 512-word RAM



Intended primarily for OEM applications, the Varispeech Model 20 module resulted from the development of a complete cassette recorder that included tape-transport and signal-amplification systems.

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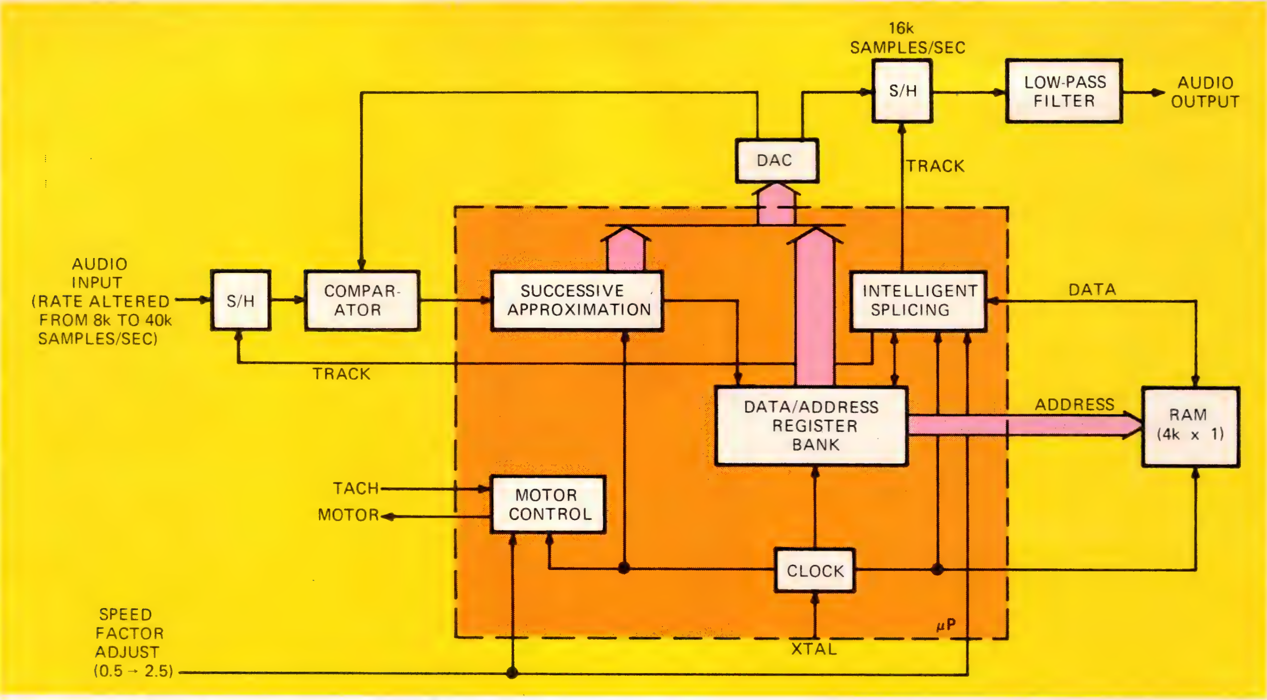

Using a novel design, this μP controls the flow of data as well as helps digitize the analog input. Thus, a single DAC handles both input and output signals, effectively adding one bit of accuracy.

sequentially stores the bits and words of input data. By "jamming" selected 8-bit data words from RAM into the DAC, this module takes only a fraction of input time to produce an analog output.

Output more speech than you input

Setting the speed-adjust factor to unity (16k samples/sec) allows input bits to replace output bits with no net gain in RAM utilization. A very perceptive reader, however, should see a potential disaster: What happens when the user slows the tape speed down (expansion mode) and the output demands more bits than those stored as inputs?

Never fear! The μP now implements a patented process known as "intelligent splicing." When the microprocessor senses that source bits will soon be exhausted (by comparing the output address in RAM with the input address), it begins to search the 20 to 30 msec of RAM that were just used as output data.

When it finds a zero crossing of the right polarity (the point, for example, where the signal value goes negative), the μP notes this RAM location. And just as the data is depleted, the μP finds another such zero crossing and jumps from this current crossing to the address of the previous zero crossing. In this manner, the microprocessor replicates tiny adjacent segments (about 20-msec wide) as required to keep pitch in sync with the altered tape speed while collecting additional data; this intelligent splice routine also eliminates annoying splice glitches.

In the compression mode (tape/speech speed increase) a similar operation occurs when the RAM is about to write new data over unused "old" data. When this function takes place, the μP jumps ahead 20-30 msec to a convenient zero-crossing splice point, thus discarding some old data but opening up additional RAM for new data.

Originally designed and sold using over four TTL boards (70 inverters, 200 NAND's, 130 flip-flops), this second-generation device has enhanced reliability and marketability by significantly reducing three factors: component count, amount of interconnect and power consumption.

μP out-performs the IBM 360

Standard Microsystems Corp. manufactures this custom n-channel hardwired chip. When asked why a custom chip was used, consultant Francis Lee explained that many options (including off-the-shelf μP's)were considered, but this function demands so much parallel activity that general-purpose devices fall far short. "I don't think a 360 could be programmed to do the job fast enough," Lee added.

As for development problems, trying to find the bugs in prototypes of the chip proved to be a real challenge, requiring quite a bit of "detective work" on the microscopic level.

What's the moral to this success story? Don't be afraid of custom μP applications. Unique demands that may not allow the use of a general-purpose μP can result in a unique product, just as in Lexicon's case. □

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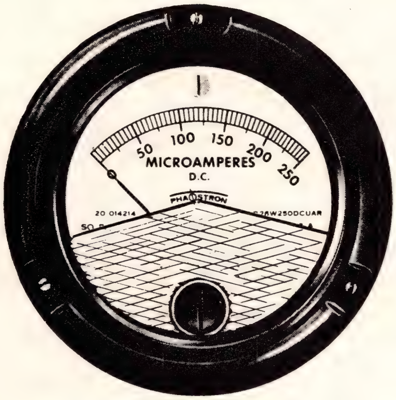
Read Some—No. 301 Read Most—No. 302

RUGGEDIZED METERS



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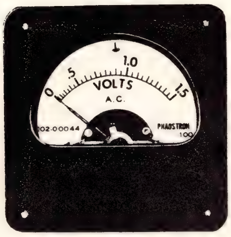

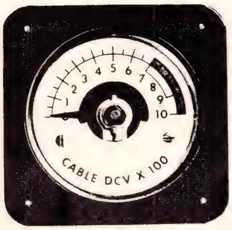

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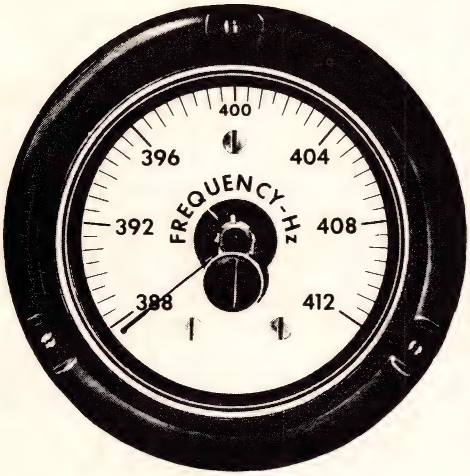

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SPECIAL REPORT

Panel Meters—analog or digital, it's the application that really counts!

How do you get the most meter for your money? What does "quality" mean? What trends are developing? Here are the experts' views.

John Conway, Associate Editor

Five years ago (or so) predictions concerning the demise of the analog panel meter (APM) ran rampant. Yet today, analog meters still coexist rather peaceably with their digital cousins. In fact, from a market-share perspective, APM's garner an estimated $80 million annually, while DPM's barely make $20 million. Are DPM's then just a flash in the proverbial pan? Emphatically NO! Each technology has simply settled into its particular niche and found contentment there (aside from some good-natured arm wrestling in the $30-$50/unit-price range, of course).

Since so much has been said recently about the A vs. D "invented controversy", we won't repeat it here. Rather, we will concentrate on what you, the overworked double-E, should know about the various meter technologies, while also pointing out what's new. In preparing our nuts-and-bolts technology update, we asked three questions of the various panel-meter manufacturers:

- What construction methods separate the good products from the bad?
- What problems continually plague analog or digital technology?
- What does the future portend?

Presenting: a few pointers on analog meters

Manufacturers of APM's provided some very interesting insights into the world of moving pointers, as these answers show:

W.M. Turner, *Annoux Corp.*

"Construction-wise, any good analog meter should have a readable pointer with a relatively vibration-free movement over a long meter life.

"While we see a marked down-trend due to over-optimistic buying late in 1975, overall the APM future holds steady growth and evolution."

Paul Bartlett, *Bartlett-Emery Inst. Co.*

"Superior analog products feature high-torque movements (in many cases custom engineered), high-energy coercive Alnico magnets, pivot and jewel suspension using spring-loaded jewel bearings, large window areas and metal fabrication of

Analog, digital or analog/digital, panel meters provide an all-important man-machine interface. The choice among them might not be as difficult as it first appears! *(Simpson Electric Co.)*

all functional parts.

"As to problems, customers are very concerned about some manufacturers' quality of construction. Some suppliers fail to hold tolerances, so durability suffers. Delivery delays are another industry problem.

"The future? The trend seems to be towards lower sensitivities."

Dan Edson, *General Electric*

"In analog construction, look for flexibility. For example, we position studs ultrasonically to match any panel cutout.

"Delivery is a major problem for some instrument manufacturers because slow delivery can delay shipment of equipment.

"GE expects the trend toward lower cost, more easily read, high-accuracy analogs to continue."

Gerry Frank, *Greibach Instruments*

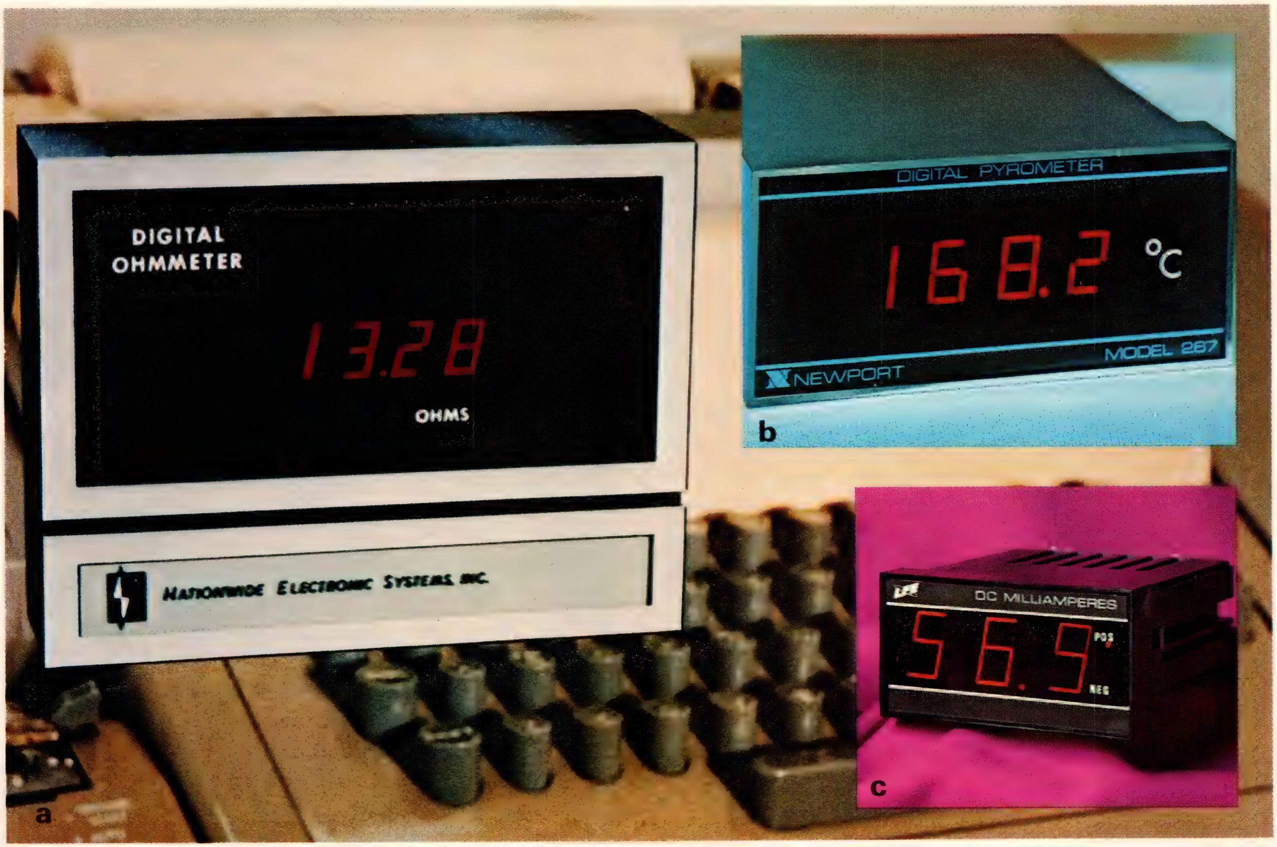
"Any good analog meter should be rugged enough to withstand shock and overloads.

"Problems we've seen include inaccurate true rms measurements of distorted waveforms and some meters' inability to measure small currents without using active circuitry."

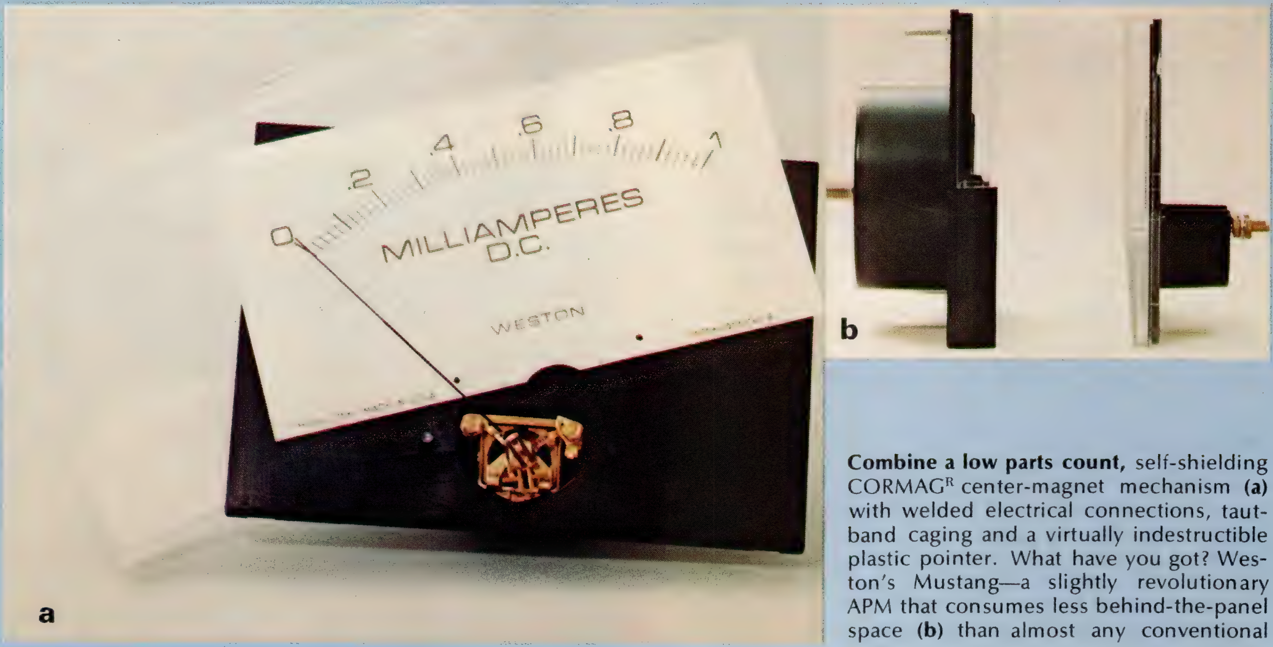
Robert Fiorille, *Hickok*

"The quality of most analog meters is reflected by their accuracy specs. Our standard is 1%.

A "now generation" functional DPM allows the user to turn a "plain vanilla" unit into virtually any kind of digital-readout device imaginable. Function cards, available in pre-assembled or stark naked versions, stack atop the DPM circuitry, adding little if any bulk to the original unit. *(Analog Devices, Inc.)*



Three meters, three cases—U.S. DPM manufacturers have yet to settle on any one set of dimensions governing case size—even though the 45×92-mm front-panel cutout DIN/NEMA specification has existed for years. Though a serious problem for OEM's looking for second-source vendors, many manufacturers feel they'd get detrimentally "locked-in" if forced to build uniformly shaped units. *(Nationwide Electronic Systems, Newport Laboratories, Inc., and LFE Corporation)*



Combine a low parts count, self-shielding CORMAG^R center-magnet mechanism **(a)** with welded electrical connections, taut-band caging and a virtually indestructible plastic pointer. What have you got? Weston's Mustang—a slightly revolutionary APM that consumes less behind-the-panel space **(b)** than almost any conventional meter.

Spring-loaded jewel bearings, removable pivots, double-cantilever anchor springs and taut-band end connections combine to make a superior APM.

"Delivery time is the industry's biggest problem right now. We recommend that users check to see if the company can deliver on short order.

"The future probably holds significant changes through development of basic materials."

R. Reardon, *Hoyt Electrical Inst.*

"Two specific construction details to look for are strong torque due to high-magnetic strength, quality pivots, and the degree of precision and care taken in the assembly of those pivots.

"Problems? None to speak of exist other than out-of-tolerance or stickiness due to customer neglect."

Steve Cohen, *Imtronics Industries Ltd.*

"We feel the use of laminate magnets in the D'Arsonval movements provides the best construction for analog meters.

"The majority of complaints we receive involve 'hung springs' caused by rough shipping. But larger magnets allow fewer turns in the spring, thereby avoiding this problem.

"Due to large panel-meter requirements for CB, a shortage of suitable magnets seems to be shaping up. Our advice? Allow longer lead times when ordering."

William Bolia, *Jewell Electrical Inst.*

"Taut-band meters provide superior service in the long haul. With regard to cases, a user 'going plastic' should try to get an acrylic or polycarbonate type.

"Delivery time really hurts customers. Any meter manufacturer worth his salt should provide fast turn-around with short lead time.

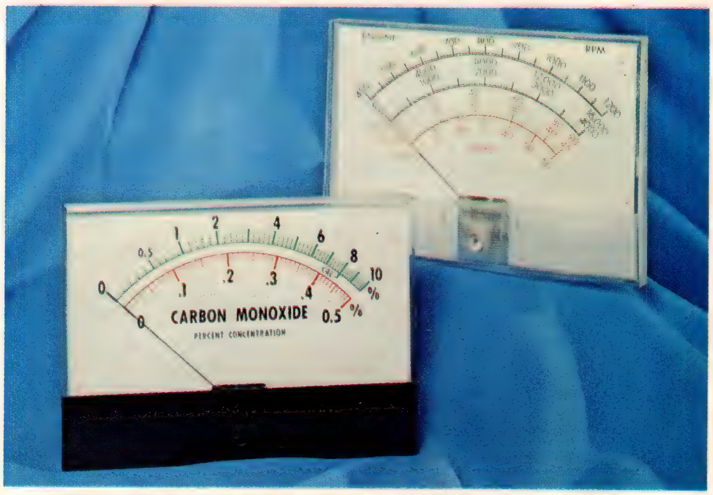
"The future? We see a trend towards behind-the-panel mounting."

David Cohen, *LFE Corp.*

"Quality products will generally have better accuracy and tracking. Users should look for a phenolic case, glass windows and taut-band construction.

"Taut-band resonance can be a problem in some APM's, but we've solved that by viscose damping.

"In the future, we see less sensitive (0-1 mA) ranges required because of less expensive op amps. We also predict an increasing demand for edgewise panel meters. Developing trends in-



D'Arsonval would be proud if he could see the analog meter still hanging in there. Noted for their low cost, reliability and quick-face-change ability, the APM is far from "gone." *(LFE Corporation)* clude lower price, moving magnet-type meters and bar-graph displays."

Hal Moore, *Phaostron Instruments*

"Core-magnet construction with spring-back jewel mechanisms makes for a very rugged product that withstands tough environmental conditions. Everyone thinks taut-band construction solves all problems. Not true! Pivot and jewel movements still remain the backbone of the industry.

"When choosing an APM, check the quality of the material used in the case. Also, check for optical clarity in the lens and printing quality of the dial. Sometimes small things flag the difference between a high-quality meter movement and an 'indicator'.

"We most frequently encounter the problem of customers writing their spec's in improper terms; for instance, 'tracking' is often interchanged with 'linearity'.

"The future will see shrinkage in the high-accuracy end of the analog-meter business due to the DPM's decreasing cost. On the other hand, we look for a big expansion in the market's low end. We also observe that more and more customers are buying movements and putting them into their own cases."

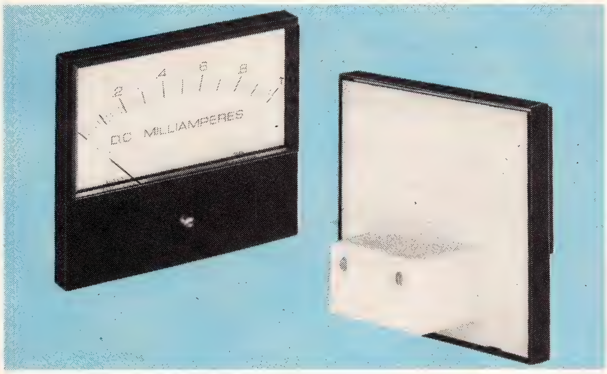
F. Fogle, *Q.V.S. Inc.*

"Construction points to look for include laminated-magnet pole pieces for high meter-to-meter consistency, cases resistant to breakage, marking and melting, and a choice of glass or plastic windows.

"Customers often overspec and that's a problem—they require unrealistic temperature compensation, accuracy, ballistics, suppression, etc. The result is increased costs and longer deliveries."

Robert Cullen, *Sigma Instruments*

"Quality analog meters have either jewel- or taut-band movements and provide 2% or better accuracy, as opposed to low-cost 'indicators' with single pivots and 5-10% accuracy.



Looks can be deceiving as this front and back view of a large-face APM shows. Technology slowly continues to advance in the world of the analog meter. Reduced movement size, increased torques and flexbility of case-styling and materials make these devices better than ever. *(Hoyt Electrical Inst. Works)*

A +131°F 3000-unit DPM rotisserie silently "burns-in" devices as automatic circuitry exercises them through a comprehensive 5-day test program. Such quality-control measures have reduced the 20-25% failure rates of dark-ages DPM's to less than 5%. *(Analogic Inc.)*

"We forsee that edgewise meters will continue to proliferate due to compactness of presentation and ease of readability, and anticipate more versions of solid-state analog meters such as our Lumigraph."

Mel Buchring, *Simpson Electric Co.*

"Full-bridge construction with nonmagnetic pivots suspended in spring-mounted jewels provide excellent repeatability, even after severe shock and vibration. Also, high-coercive magnets offer accurate, long-term calibration.

"Probably the most frequent problem we encounter is the tendency for customers to overspecify. By reviewing with them their actual needs for accuracy, tracking balance, coil resistance and tolerances, we can reduce cost and provide a more suitable meter for the application.

"The analog indicating meter has reached a

Table 1—Analog Panel Meters

Advantages over other technologies:
- small size
- low cost
- high reliability
- no external power required
- relatively "noise-proof"
- trend information easily shown
- relative value to full scale easily shown
- virtually infinite line/supply rejection

Construction to look for:
- in vibrational environments—pivot and jewel movements
- in vibrationless (or min. vibration) environments—taut-band movements
- mechanical flexibility of case layout, dimensions, meter face, lens, construction material, etc.
- high-torque movements
- environmental protection (waterproof, etc.)
- snug (but not tight) component fit

Problems commonly encountered:
- delivery delays
- some delays and/or cost overruns due to lack of application knowledge
- environmental problems
- vibration damage with taut-band-type meter movements
- delays and/or cost overruns due to overspecification
- awkward recalibration
- poor quality control
- susceptibility to shock
- poor overrange protection

What the future holds:
- lower costs
- increased use of edgewise types
- further introduction and use of analog-digital types (bar graphs)
- introduction of "dual" meters (i.e., analog and digital in one case)
- less use and manufacturing of high-accuracy types
- increased use and manufacturing of taut-band types
- possible overall decrease in use of instrument quality types with demand for simple indicating types

stage where refinement rather than basic changes will provide the key for new development. New magnetic materials will, no doubt, improve full-scale sensitivity; more meters will have taut-band suspensions; and case styles will continue to move toward edgewise displays to save panel space."

Dr. Roland Gubisch, *Weston (Analog)*

"My advice on construction is: Look for thick rigid parts (plastic, glass or metal); avoid delicate appearance except where function dictates (coil, pivots, etc.); look for tight-fitting parts but not press-fit construction (which generates shavings and 'trash' that can cause friction) and for welded electrical connections (more reliable than solder) or bright solder for soldered types. Leads should be clamped or dressed carefully to avoid vibration fatigue or interference with the moving coil.

"I feel that a lack of meter application knowledge causes major problems for some customers. Product availability can also be of critical concern.

"The future holds a trend to less costly analog indicators."

Jack Stenga, *Yokogawa Corp.*

"Since specifications can deceive, the only true test of a good analog meter is an actual 'in-plant' evaluation. Top manufacturers offer units for such evaluation to make sure the instrument 'fits' the application.

"Since customers naturally want the lowest cost but 'Cadillac' performance, specifying the proper meter for the job is the customer's biggest problem.

"High-priced analogs ($30-$50) continue to bow to DPM's but lower priced APM's will show market growth."

Table 1 condenses and summarizes these APM comments.

Meanwhile, back in the digital world...

Following our conversations with manufacturers of analog meters, we crossed over into the digital domain asking, in essence, the same questions. Their responses follow:

Pollens and Codispoti, *Analog Devices*

"Since reliability is the all-important common denominator, ask the manufacturers for their return rate percentages. Not too many years ago, return rates ran 20 to 25%, but today, they should be less than 5%—accept nothing greater. We also find that noise problems and display failure—annoyances that apparently plagued other manufacturers in days past—haven't troubled us at all.

"The future? We suspect that a new generation of DPM is about due and that DPM sales-growth curves will continue their upward trend."

Gordon, Culverhouse & Seperant, *Analogic*

"The quality of DPM construction and the problems encountered go 'hand-in-glove.' First of all, you must realize that digital meters will possibly never offer the reliability of analog meters. Nevertheless, reliability will always separate the good from the bad, the useful from the useless. With this thought in mind, then, prospective DPM users should ask certain key questions of the manufacturers under consideration prior to inking the purchase order.

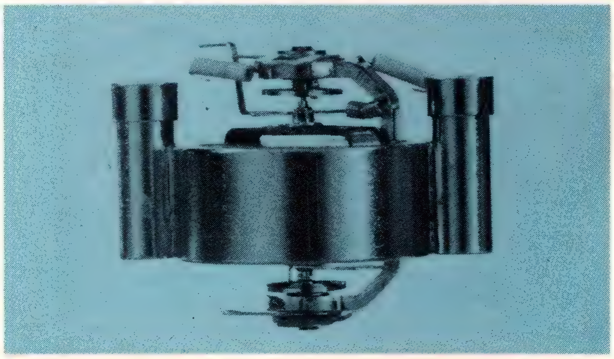
"For instance, ask for meantime-between-failure figures (MTBF)—the answer almost always 'tells all.' Any manufacturer who cares enough about his own products and his customer's satisfaction will give this information without hesitation. His failure to do so might indicate problems.

"Ask what the internal temperature rise equals during operation. Since most of today's quality DPM's utilize low-power circuitry, look for rises on the order of 10-15°F. Temperature differentials significantly greater than this usually flag power-hungry digital 'beasties' and/or sloppy circuit design. Our experience shows that a 40° rise, for example, reduces MTBF by a factor of two!

"Also, ask for an evaluation sample, and upon receipt pop its lid and examine the density, quality and layout of the internal components. Such seemingly mundane items as transformers, resistor networks, LED- or GAS-type readout, regulators, trim pots, etc., drastically affect meter performance when taken 'in toto.' You wouldn't believe the difference 30 cents makes in the quality of a trim pot.

"Finally, examine the case. If it has ventilation holes, convection might carry circuit-zapping dust, dirt moisture, etc. into vital areas. Holes might also indicate temperature-rise problems.

"The list of questions can go on and on—how



All alone and lonely, sales of bare-bones analog-meter movements continue to boom. How come? OEM's in many cases find it more practical to supply their own custom "exteriors and trimmings." *(Phaostron Instrument Co.)*

long is burn-in?...what QC and QA procedures are taken (vibration, humidity, etc. tests?) etc. Our advice? As you put forth your queries, always keep your application in mind.

''...Regarding the future, we see ever-increasing DPM reliability with a trend towards 'dedicated DPM' or, as some now call them, Digital Panel Instruments (DPI's). As for price, quality line-powered 3-1/2-digit DPM's will never cost less than $50-$60.''

Pete Muller, *California Instruments*

"The most frequent complaint we hear from customers is that some manufacturers promise resolution that their DPM's can't deliver. Be careful here.

"The future? Most likely the smaller companies will get squeezed out of the low-resolution (and by that I mean 3- to 4-1/2-digit!) markets by the heavyweights."

Gallagher, Copeland and **Phillips,** *Datel Systems*

"From the viewpoint of construction, look for components not mounted in sockets (i.e., those directly soldered to the pc board). Sockets, in our opinion, imply a greater chance of poor connection and indicate components with high failure rates or components that weren't tested with the whole meter.

"Experience shows that a 'last-digit-jitter' problem frequently exists in competitive units. Usually caused by DPM thermal noise or ac hum on the input, this type of jitter sometimes indicates a poorly regulated power supply with unfiltered logic noise. Input filters can help, but they add long settling time in the last digit.

"Far into the future we forsee a LED bar-type display with a single traveling bar, as well as very compact meters about two inches wide with extensive LSI, monolithic and/or hybrid construction and prices at $15-$20 in substantial quantities. We also envision very thin LED DPM's (also LSI) with integral red-glass filter/case header. Perhaps we'll even see a DPM on a DIP—the technology exists, but does the market?"

A new concept in indication and alarm-control instrumentation, Sigma's Lumigraph is a totally electronic analog display. It uses 200 closely spaced neon-discharge elements to show accurately (and at a glance) the measured value relative to F.S. values and/or adjacent set-point bars.

E.B. Hibbs Jr., *Digilin Inc.*

"When examining a DPM, ask yourself: 'Is it reliable? Is it rugged?' If you can honestly answer 'yes' to both questions, odds are it's a good product.

"The problem that we most often encounter is a general lack of application information. To this end, we've tripled our applications staff.

"In the future, small companies like ourselves will go more into value-added meters; i.e., devices with on-board interface and signal-processing circuitry. Semiconductor houses will likewise pursue the high-volume 'standard' unit market."

Dick Dale, *Digitec*

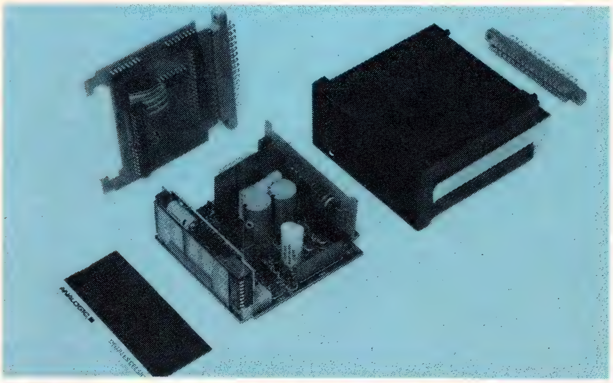
"Quality DPM's usually have all IC's and LED's in sockets for servicing flexibility, standup boards with mechanical supports, pc lands that do not run under active components, and transformers and supplies that are 'oversized' and conservatively rated.

"Problems that aggravate many DPM users include system-interface difficulties and system-generated noise. Thus buyers should ask if the units feature a high-noise immunity design.

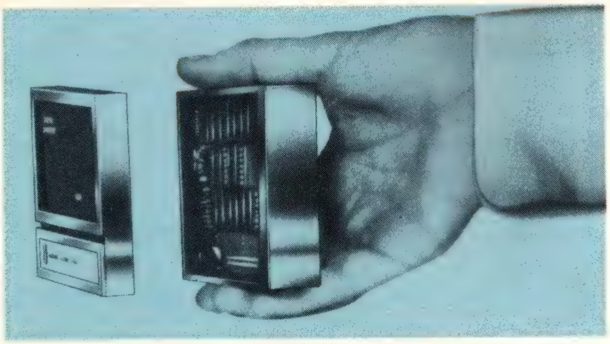
"Over the next few years, certain DPM products will 'fall out'. Of course, quality instrument-type devices will always have a market, but low-cost, low-quality DPM's will lose to 'in-house' design."

William D. Cook, *Electronic Research Co.*

"Properly constructed DPM's are precise instruments and should therefore have a crystal



A DPM that enjoys being a kluge? That's right! Analogic's Models AN2553 and AN2559 accept both analog and digital plug-in interface "kluge" cards that utilize both the power and space available in the basic empty-headed meter to turn same into stand-alone digital panel-instrument subsystems. Functional cards can be purchased "off-the-shelf" in a variety of configurations, or blank, for the "roll-your-own" crowd.



Hate to cut holes in things? Nationwide Electronic Systems Inc. produces a whole family of Slimline^R digital panel instruments that mount directly on an instrument enclosure's front panel. Measuring only 3-1/2×4-1/2×5/8 in., all units boast pin-for-pin compatibility and interface with an almost equally slim "ASCII Bustle" that makes each meter TTY, CRT, modem, computer and data-handling equipment compatible.

time base instead of the inferior line-frequency counters or RC/LC oscillators.

"Good manufacturers prevent application problems by providing prolific, complete and simply written documentation.

"Not too long from now, DPM's will be battery powered by throwaway batteries lasting six months to a year or more."

Eppard and **Pierce,** *Electro-Numerics, Inc.*

"In high-end, multifunction DPM's, top quality meters have tight specs: accuracy, temperature stability, linearity and internal noise-immunity. Since a user can check quality only by obtaining samples and testing them in the application, the best manufacturers offer such samples.

"Features to check include the size and brightness of the display and the quality of the case and components. Low-quality DPM's, for example, won't have gold-plated, circuit-board contacts. However, low-priced units aren't necessarily bad unless they fail to meet a customer's specific requirements.

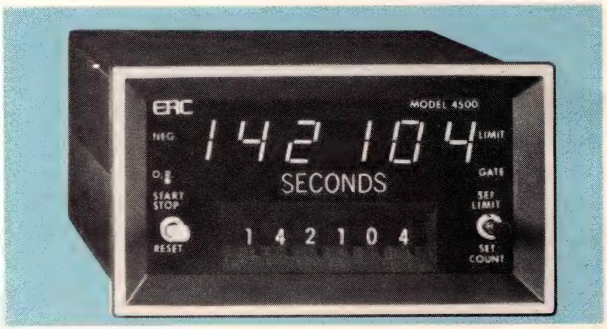
Designed to replace electro-mechanical counters, Dynamics Electronic Products' Minicounter II is a stripped-down but highly functional 8-digit (LED) counter able to operate at speeds to 12,000 counts/min. Since this unit triggers on any pulse between 3-100V having a 2.5-msec width, TTL, DTL, CMOS or virtually any "homebrew" logic signal will work.

"The main problems DPM customers face revolve around reliability and delivery. Though a DPM is small, it's a key component in an instrument or system that represents a large sale for the manufacturer. If the meter fails, the product fails. To this end, ask the DPM manufacturer how long his warranty lasts. Ours, for instance, is two years long.

"Over the next few years we think two key trends will develop: a flattening of price (barring major 'tech' breakthroughs) and a division of the market into separate, but not mutually exclusive, segments: high-quality, broad-capability meters and lower priced meters with a basic readout function."

Harold Steinburg, *Gralex Industries*

"Four things to look for when buying a DPM are screw-down locking of pc boards, positive filter retention, uncrowded pc-board construction and sockets for all LSI devices.



A counter more in control of itself, Electronic Research's 6-digit Series 4500 DPM functions as a presettable, bi-directional counter/timer/controller. The unit accepts low-level sine waves, TTL and/or MOS signals and contact-closure inputs as fast as 10 kHz (1 MHz available!).

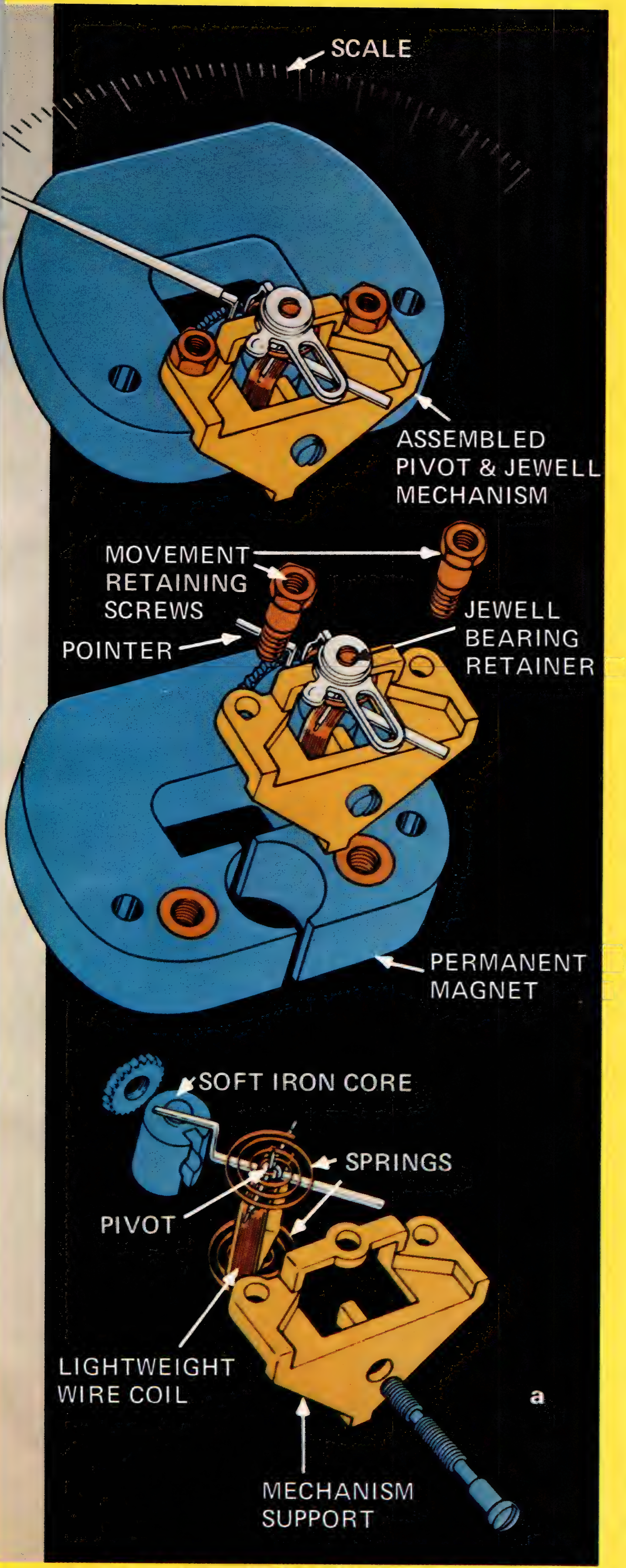
"Problems? Mechanical installation difficulties and ground-loop generation (with BCD-output type meters) are two major concerns. We overcome these by providing custom packages and isolating the BCD outputs, respectively.

"As for the future, we see smaller DPM's with larger digits, shakeout in case standards, a resolution of the English-vs.-metric dimension conflict and increased use of LCD's."

Bob Lounsbury, *Nationwide Electronic System*

"A shopping list of quality construction 'look-for's' should probably include full-parallel data inputs and outputs, hidden manual controls and adjustments to discourage tampering, a calibration-adjust pot, a valid-data (data-ready) output signal, output latch controls, a long-term warranty, user-testable spec's, remote-supply ability to reduce noise and a product line with depth.

"It's almost impossible to name a select group of frequently encountered problems, but gener-



Courtesy *PHAOSTRON INSTRUMENT CO.*

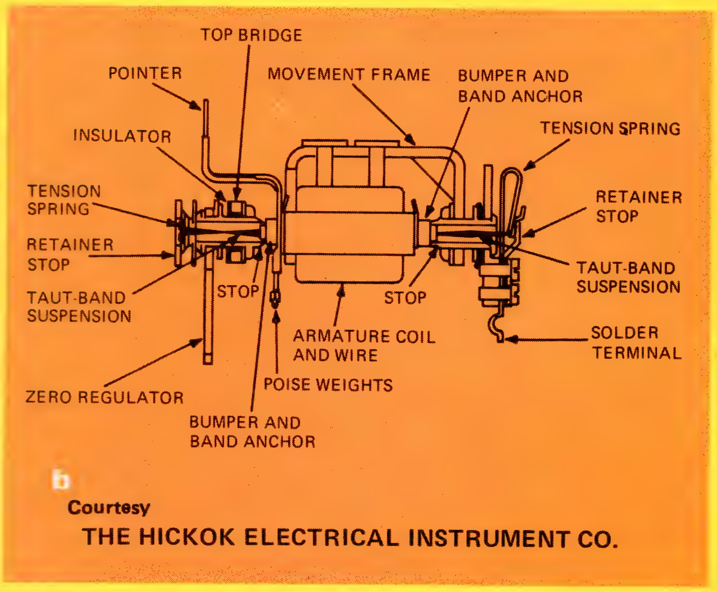
What they are and how they work

Don't let panel-meter buzzwords get you down. Here are some thumbnail definitions.

Pivot and jewel movement—In essence, this consists of simply a low-mass coil of wire (**Fig. a**), supported on and by tiny jewelled bearings, and mounted between the poles of a permanent magnet. As current flows through the coil, a magnetic-field interaction causes pointer rotation.

Taut-band suspension—In this case, the movement (**Fig. b**) is suspended by thin conducting "ribbons" under tension. As current flows through the movement coil, these ribbons keep the side-to-side motion within design tolerances but still allow the meter to be mounted in virtually any position. Standing wave vibration, however, can lead to this APM's downfall.

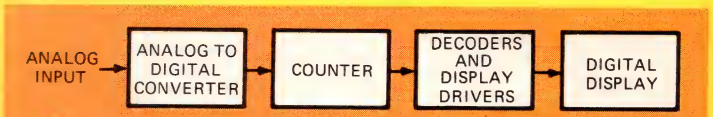
Digital panel meter—For the record, **Fig. c** "blocks out" the internal arrangement of a DPM. Troubles usually occur in either the A/D converter stage—which drifts with time—or in the display itself. The failure of just one segment in a DPM in effect destroys the usefulness of the entire unit!



b

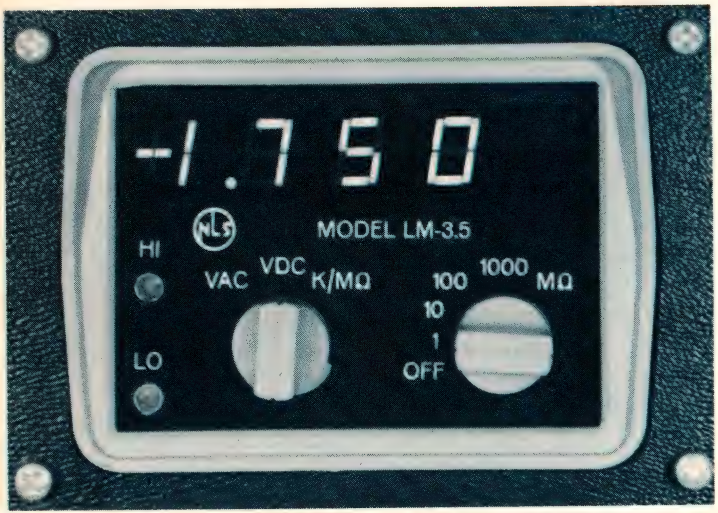
Courtesy

THE HICKOK ELECTRICAL INSTRUMENT CO.

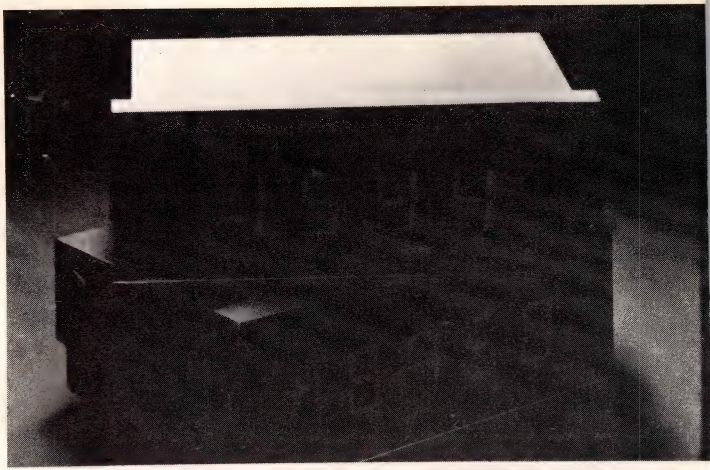


c

DPM



When can a DPM stop calling itself a DPM? Maybe when it's a VOM! Non-linear System's Volksmeter family demonstrates just how far panel-mounted technology has progressed. Operating from their own internal Ni-Cd battery pack or on 115V ac, these units measure voltage, current and resistance across a wide dynamic range.



Sending a shock wave through the industry, Fairchild Camera and Instrument Co.'s sudden appearance on the DPM scene has many manufacturers trembling—as they scratch their heads. Will the implied threat of greatly decreased prices, due to vertical integration, ever materialize? Only time will tell!

ally DPM glitches revolve around attempts at improved productability, cost reductions, and improved test-data consistency.

"In the future, low-cost instruments with little data interface, etc., and higher cost devices with new features but stable prices will appear on the DPM market."

Lyell Kinney, *Newport Laboratories*

"Quality comes with good design, good components conservatively applied, careful construction, tight QC, thoughtful test and checkout and long-term burn-in of the finished product. At burn-in, not only the ambient temperature but also the meter's signal input and power supply should be exercised.

"A responsible manufacturer will provide a wide range of instrumentation, not just voltage and current meters. It should offer DPM's that handle frequency (especially RPM), temperature and time, as well as models that offer engineering units display, data recording and multipoint scanning.

"We think that the future holds a dramatic reduction in prices, with a trend to more useful 'smart' meters using μP's and calculator chips."

Phillip Akin, *Non-Linear Systems Inc.*

"With the trend toward digital display in lieu of pointer-type meters, many companies are looking for a DPM that can replace the APM in their instruments without requiring a complete redesign. In turn, this often means that the DPM must by physically small. At the same time, the engineer must worry about power requirements of the digital replacement; i.e., the DPM must not overtax the instrument's built-in power supply.

Still another important factor is the zero of the meter. Analog panel meters have zero adjustments that often must be readjusted when the instrument is moved. On the other hand, digital meters can provide a true zero independent of position, temperature and supply voltage if they incorporate an auto-zero circuit. We therefore highly recommend the auto-zero feature to most users.

"Problems most encountered involve special requirements associated with the circuit driving the display. With pointer meters, scaling and offset are readily accomplished with pen and ink, but digital meters require circuit changes for these functions. Other typical DPM requirements are for various ranges, voltmeter and counter operation, lamp test, leading-zero suppression, blanking, display-intensity control, different-color display and special supply voltage.

"Low quality and long delivery times, plus nonconcurrence with published specifications are other problems that customers have experienced with competitors' products.

"The future will probably provide more flexible DPM's that will tend to eliminate 'specials.' Today, if a meter met all special requirements and could thus be used universally, no one could afford it.

"Development and cost reduction in microprocessors will lead to a new generation of 'smart' DPM's—for instance, a true 'one-chip' meter that could provide trend indication as well as present value. Such a meter could also provide alarm output; high-low limit output; peak-reading hold; proportional control signals; linear or logrithmic display of input signal and frequency selectivity for ac signals—all at a lower cost than today's DPM's and in a smaller package."

R.D. Zimmer, *Pulse Dynamics Mfg. Co.*

"Look for injection-molded cases of fire-retardant cycolac, signal and power-supply inputs with slide-on connectors, wire-wrap or solder terminals and ±10% calibration adjust.

"The future trend will be toward LED readouts in VU and S scales as production rates increase and costs decrease."

George Obinger, *Velonex*

"I have just one small piece of advice—open the meter case. One look will tell all.

"With respect to problems—improper grounding when connecting the unit to power causes more headaches than you'd believe.

"The future? You can expect smaller sizes, lower power requirements, and increased ruggedization to withstand hostile environments."

Table 2 summarizes the results of our DPM survey. ☐

Table 2—Digital Panel Meters

Advantages over other technologies:
- high accuracy
- readability at great distances and in lighted or dark environments
- no parallax error
- instant response
- no overshoot
- easily calibrated
- BCD, tri-state and other computer-interfaceable outputs
- no magnetic-field problems
- excellent linearity
- simplified scaling
- "sexy" display

Construction points to look for:
- low parts-count "innards"
- a variety of available displays (LED, LCD, GAS PLANAR, etc.)
- 0.5-in. displays or larger
- easily accessed calibration pots (but tamper-resistant)
- pc lands not under active components
- a minimum of holes in the case (reduces dirt intake and indicates small temperature rise)
- crystal time base
- low-power (MOS) circuitry
- use of LSI devices
- gold-plated contacts
- case following NEMA standards
- extensive "burn-in" and test procedures
- high MTBF figures

Problems commonly encountered:
- high cost
- digit jitter
- display failure
- noise problems due to lax circuit design, improper grounding, etc.
- circuit failure
- internal or external power-supply-problems
- virtually no true second-sourcing
- awkward size

What the future holds:
- reduced cost
- smaller case dimensions
- increased display size
- more "instrument"- or "system"-type meters
- intelligent µP-based meters
- µ-peripheral-type meters
- increased reliability

PANEL METER MANUFACTURERS

To help you get further information on the products discussed in this article, here is a list of manufacturers. We thank them for providing material and for answering our questions. By circling the appropriate numbers you will receive information from the companies.

	APM Circle No. 319	DPM Circle No. 320
Analog Devices Box 280 Norwood, MA 02062 (617) 329-4700		●
Analogic Audubon Rd. Wakefield, MA 01880 (617) 246-0300		●
Arnoux Corp. 35 Anacapa St. Santa Barbara, CA 93101 (805) 963-3476	●	
Bartlett-Emery Inst. Co. 14th St. and Ave. M. Fort Madison, IA 52627 (319) 372-8366	●	
Beckman Instruments, Inc. 2500 Harbor Blvd. Fullerton, CA 92634 (714) 871-4848		●
California Instruments Co. 5150 Convoy St. San Diego, CA 92111 (714) 279-8620		●
Datel Systems, Inc. 1020 Turnpike St. Canton, MA 02021 (617) 828-8000		●
Digilin 3521 W. Pacific Ave. Burbank, CA 91505 (213) 846-1800		●
Digitec 918 Woodley Rd. Dayton, OH 45403 (513) 254-6251		●
Doric Scientific 3883 Ruffin Rd. San Diego, CA 92123 (714) 565-4415		●
Dynamics Electronic Products 9001 Fullbright Ave. Chatsworth, CA 91311 (213) 998-0121		●
Electronic Research Box 913 Shawnee Mission, KS 66201 (913) 631-6700		●
Electro-Numerics, Inc. 1811 Reynolds St. Irvine, CA 92714 (714) 549-8821		●
General Electric Instrument Products 40 Federal St. Lynn, MA 01910 (617) 594-5547	●	
Gralex Industries 155 Marine St. Farmingdale, NY 11735 (516) 694-3607		●
Greibach Instruments 25 Dock St. Mt. Vernon, NY 10550 (914) 699-9717	●	
Hickok Instrumentation 10514 Dupont Ave. Cleveland, OH 44108 (216) 541-8060	●	
Hoyt Electrical Inst. Works 556 Trapelo Rd. Belmont, MA 02179 (617) 489-1520	●	
Imtronics Industries Ltd. 813 Second St. Ronkonkoma, NY 11779 (516) 981-3434	●	
Jewell Electrical Inst. Inc. Grenier Field Manchester, NH 03108 (603) 669-6400	●	
LFE Corporation 1601 Trapelo Rd. Waltham, MA 02154 (617) 890-2000	●	●
Nationwide Electronic Systems 1536 Brandy Parkway Streamwood, IL 60103 (312) 289-8820		●
Newport Laboratories Inc. 630 E. Young St. Santa Ana, CA 92705 (714) 540-4914		●
Non-linear Systems Inc. Box N Del Mar, CA 92014 (714) 755-1134		●
Omega Engineering Inc. Box 4047 Stamford, CT 06907 (203) 359-1660	●	●
Phaostron Instrument Co. 151 Pasadena Ave. South Pasadena, CA 11704 (213) 255-1471	●	
Prime Instruments Inc. 9805 Walford Ave. Cleveland, OH 44102 (216) 651-0400	●	
Pulse Dynamics Mfg. Corp. Box 355 Colchester, IL 62326 (309) 776-4544		●
Q.V.S. 20 N. 15th St. East Orange, NJ 07017 (201) 673-3996	●	
Sigma Instruments Inc. 170 Pearl St. Braintree, MA 02184 (617) 843-5000	●	●
Simpson Electric Co. 853 Dundee Ave. Elgin, IL 60120 (312) 697-2260	●	●
Triplett Corp. 286 Harmon Rd. Bluffton, OH 45817 (419) 358-5015	●	●
Velonex 560 Robert Ave. Santa Clara, CA 95050 (408) 244-7370		●
Westach Mfg. Co. 3400 Westach Way Sonoma, CA 95476 (707) 938-2121	●	
Weston Instruments 614 Frelinghuysen Ave. Newark, NJ 07114 (201) 242-2600	●	●
Yokogawa Corp. of America, 5 Westchester Plaza Elmsford, NY 10523 (914) 592-6767	●	

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  - **Pioneer Dayton Inst. Lab.
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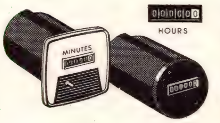
GENERAL ELECTRIC

How to pick the right time meter for your product.

The right elapsed-time meter can add to your product's quality and saleability in two key ways: Performance and appearance. So it pays to evaluate time meters carefully. Many designers today do just that . . . by following these seven easy steps.

1 Decide whether you want to measure minutes or hours.



The application of your product will usually decide this for you. If it is to run long cycle, then you want an hour meter. If the cycle is short, then a minute meter is correct.

GE time meters are available to measure either... always with a 6-digit readout.

2 Reset or non-reset?

GE's reset version uses a simple pushbutton.

Will your product's application call for a continuous time reading? Then you want a non-reset time meter no one can tamper with. But if it's repeated measurements you need, then you'll want to include an easy-to-use reset feature.

3 Choose the style, size and shape that will look best on your panel.

Smart looks can sell. Your product's time meter may be the very first "embellishment" your customer notices.

GE choices include BIG LOOK® styling to match your other panel meters. Also, back-of-panel mounting, square, round, etc.

4 Be sure you have the right voltage and frequency rating.

Time meters are designed for 120, 208, 240, or 480 volts ac; and 50 or 60 Hertz.

5 Consider mounting flexibility before you have to change a time meter.

Make sure the time meter you pick is one that can be easily replaced later. And, of course, make sure it will fit your panel's existing mounting holes.

GE time meters offer a variety of mounting-stud positions to fit your panel cutouts.

6 Run through this quick reliability checklist.

(A) Is the time meter you are considering UL-recognized? (B) What's the performance record of the motor that drives its digits? (C) Will the time-keeping mechanism require much maintenance? (D) How tough and protective are the materials in its outside case? Be sure you've found the answers to these questions before you specify.

7 Finally, don't overlook the reputation of the manufacturer.

Make sure your time meter manufacturer has a record of dependability, that he will stand behind his product, and that his time meters meet all ANSI specifications.

For a free guide entitled, "Pick the Right Panel Meter" (GEA-10340) and our complete Catalog (GEP-307) write to General Electric Co., Section 592-66, Schenectady, N.Y. 12345.

Specify General Electric... just for good measure.

592-66

GENERAL ELECTRIC

For more information, Circle No. 33

Stretch your test instrument budge
B&K-PRECISION
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Does a scope always have to be expensive to meet your needs? At B&K-PRECISION we don't think so. B&K-PRECISION offers a full line of scopes that give you the performance and features you need, at substantial cost savings...plus the advantage of immediate delivery and 10-day free trial through local distributors.

B&K-PRECISION has taken a no nonsense, cost-effective, approach to oscilloscope design. All our scopes will trigger at frequencies typically 50 to 100% beyond their rated band-width. They are rugged, dependable instruments, designed to match the features and performance of far more expensive scopes, without matching their high price. An important part of our approach is that you shouldn't have to buy more scope than you need to get the features you want. Before making your next purchase, compare the features and performance you require with what we have to offer. You'll discover that your budget is a lot bigger than you first thought!

30MHz Dual-Trace 5″ Triggered Scope with Signal Delay

For the engineer who requires a full-feature 30MHz scope

- Built-in signal delay line permits viewing of high-frequency pulse risetimes
- Triggers on signals up to 50MHz
- Rise time 11.7nS
- 20 calibrated sweeps – 0.2 μS/cm-0.5S/cm
- Built-in high and low-pass filters
- 5mV/cm vertical sensitivity
- Illuminated graticule
- TTL compatible intensity modulation
- X-Y capability using matched DC amplifiers
- P31 blue phosphor
- Internal .5Vp-p ±1% calibration source
- 5mV/cm horizontal sensitivity.

Model 1474 $820 (not including probes)

15MHz Dual-Trace 5″ Triggered Scope

Premium features and performance in a 15MHz dual-trace scope

- Ultra – flat in-band response with smooth rolloff past 15MHz
- Triggers beyond 27MHz
- 24nS risetime
- 19 calibrated sweeps – .5 μS/cm-0.5S/cm
- 10mV/cm vertical sensitivity
- Algebraic addition and subtraction
- Illuminated graticule
- X-Y capability using matched DC amplifiers
- P31 blue phosphor
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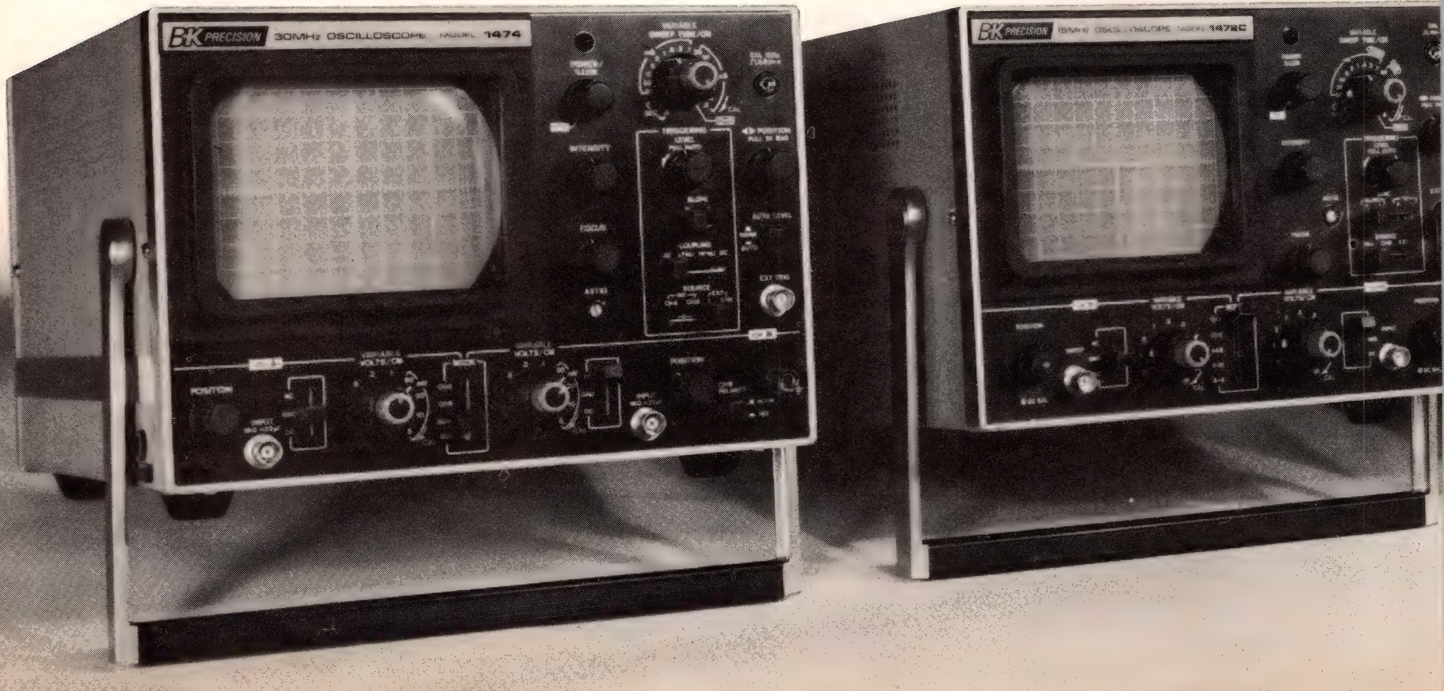
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A 3-state phase detector can improve your next PLL design

Amazingly simple, this technique boasts wider operating ranges and needs less output filtering. Do you know the principles involved?

C. Andrew Sharpe, The Bendix Corp.

The growing army of digital and analog users of phase-locked loops (PLL's) already know that PLL's are superior to standard detection methods. These control devices can readily restore phase (and frequency) of a signal drowned in noise.

A key element in a PLL is the phase detector, which typically is of the cross-coupled latch, set-reset flip-flop, or exclusive-OR variety. Unfortunately, these phase-detector circuits, although simple with respect to hardware, suffer from several major drawbacks:

- The output information for phase detection is contained in the width of the output pulse, which requires substantial filtering to remove the reference frequency content.
- This class of detectors often responds to harmonics of the input signals, restricting the operating range of the input frequency.
- If some type of memory does not detect a frequency difference, the capture range (maximum frequency difference between the two inputs before the system can start to lock) is one of the design variables that directly oppose the other loop constraints, such as filtering and external noise.

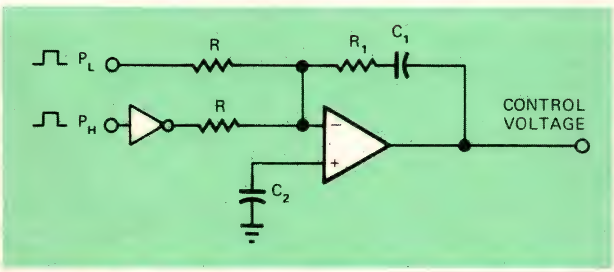


Fig. 1—A positive input on P_L lowers the control voltage, while a positive input on P_H causes it to rise. The very small pulse width required to compensate for op-amp leakage and finite gain has an unusually low reference component.

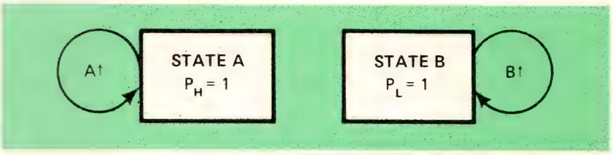


Fig. 2—Since the machine has two output lines, two states are immediately evident: states A and B, one for $f_A > f_B$, the other for $f_B > f_A$. When the machine is in state A, repetitive positive transitions on its A input will not change the state.

The 3-state phase detector, however, eliminates these objections.

Control is the goal

This new approach to phase detection can best be understood by considering how the op-amp arrangement of **Fig. 1** generates a control voltage to drive the variable phase/frequency element. Observe that a positive input on P_L will lower the control voltage, while a positive input on P_H will cause it to rise. If $P_L = P_H$, no change in the control voltage will occur.

With this method of control-voltage generation, then, the problem of frequency/phase detection reduces to activating the proper input line that will drive the circuit into lock. Once phase lock is established, the operation requires no further change in control voltage, and neither line will be active. (Of course, the latter is an idealized condition, since leakage currents and finite op-amp gain always require some average voltage out of the phase detector. Nevertheless, the very small pulse width typically required has a

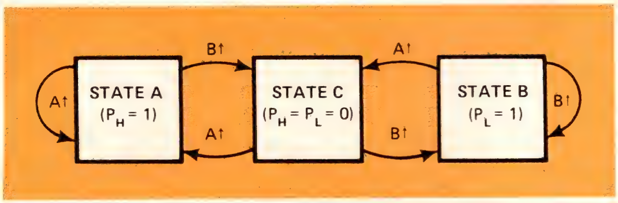


Fig. 3—A single positive transition on input B (or A) after repeated transitions on A (or B) sends the machine to state C, where both outputs are low—even if both frequencies are unequal. As the frequencies begin to track, the width of the pumping pulse will be directly proportional to the phase difference.

reference component substantially smaller than that produced by the previously mentioned techniques.)

"State-ing" the problem

Before we can develop a suitable digital control circuit, we must establish some fundamental laws of frequency comparison:

- For two pulse trains, if $f_A > f_B$, then at some point in time two or more reference transitions of pulse train A will occur between two reference transitions of pulse train B.
- If $f_A = f_B$, at no time will two reference transitions of pulse train A occur between two reference transitions of B.

By applying these postulates, you can build a 3-state phase detector in a manner that avoids the traditional and lengthy asynchronous-machine design problem. The goal is to combine logic devices that will:

- provide positive pulses on output line one if $f_A > f_B$, a condition which may be detected by looking for two consecutive pulses on the A input line
- provide pulses on output line two if $f_B > f_A$
- hold HIGH output line one for the duration of the phase difference if $f_A = f_B$ and the positive transition of A leads that of B
- hold HIGH output line two for the duration of the phase difference if $f_A = f_B$ and the positive transition of B leads that of A.

By defining two output lines for the machine, then, two states are immediately evident as shown in **Fig. 2.**

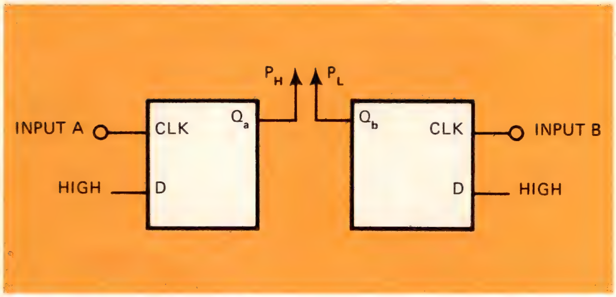


Fig. 4—A leading-edge triggered "D" type flip-flop with its "D" input tied high satisfies the requirements of states A and B.

Three states are better than two

If the machine is in state A (or B), repetitive positive transitions on the A (or B) input will obviously have no effect on that state. But if a transition should occur on B (or A) after consecutive transitions on A (or B), you do not want to go directly to state B (or A). Why? Because if state A does transition directly to state B, one output will always be HIGH, thus violating the criteria that $P_L = P_H =$ ZERO when $f_A = f_B$ and the phase angle equals zero. Getting around this problem requires adding an intermediate third state, C, to the machine **(Fig. 3).**

Now, a positive transition on the B (or A) input occurring after repetitive transitions on the A (or B) input will send the machine to state C. At state C outputs P_H and P_L both will be LOW (no pumping action). Notice here that regardless of the initial state, two such transitions on the A (or B) input will put the machine into state A (or B) signifying that the A (or B) input has the higher repetition rate.

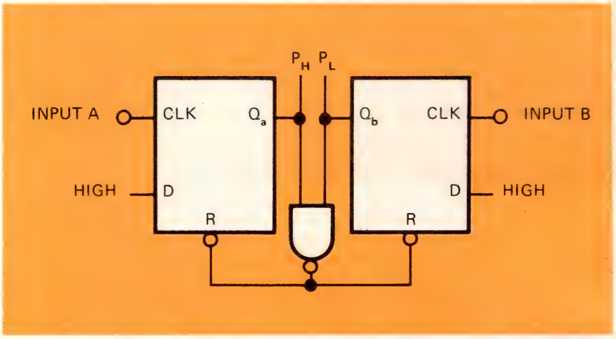


Fig. 5—State C is easily achieved by adding a NAND gate that resets the state A and B flip-flops. This, then, is the basic dual-D phase/frequency detector.

Phasing out your differences

As the rate of A (or B) decreases to equal B (or A), the inputs to the machine will have the phase of A (or B) leading the phase of B (or A). This results in the same output being held HIGH for both higher frequency and leading phase, satisfying all of the goals previously stated.

When the machine is initially turned on, it can be in any of the three states. But as soon as two consecutive transitions appear on one of the inputs, the machine will go to the state with the higher input frequency and then alternate between that state and state C. Note that only the state corresponding to the input line of higher frequency will be pulsed HIGH.

As the frequencies become identical, the width of the pumping pulse will be directly proportional to the phase differences. And as the phase difference approaches zero, the output pulse also will become zero.

This completes the state diagram for a 3-state

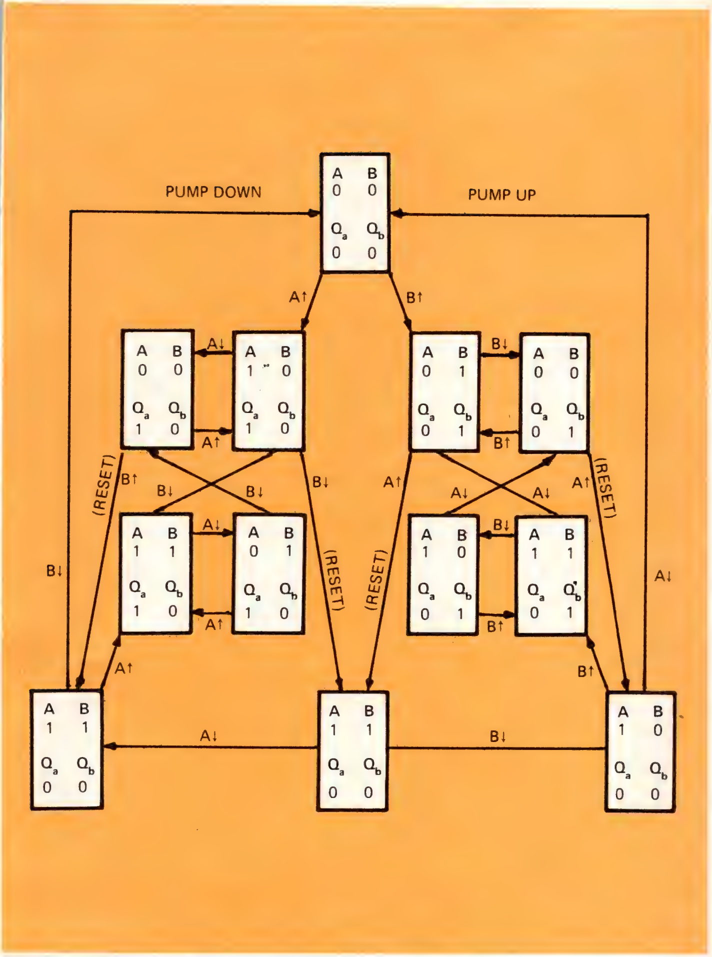


Fig. 6—This state-transition diagram explores all possible input/output conditions of the dual-D flip-flop 3-state circuit of **Fig. 5.**

phase/frequency detector. Since the dynamic characteristics of this particular state map are based on positive transitions, implementation must be accomplished by using a storage element that changes states only on positive transitions. Rather than attempt the classical exercise in asynchronous machines, the following method simplifies the design procedure considerably.

Okay, bring on the hardware

Since states A and B respond identically to their A and B inputs, the same circuit can be used for both, taking advantage of symmetry. Recall that once either state has been reached by a positive input transition, the circuit's output must remain HIGH for consecutive positive transitions. A leading-edge triggered type-D flip-flop with the input tied HIGH meets this requirement (**Fig. 4**).

In a state C network, if the machine is in either state A or B, a transition on the opposite input must reset both output lines to ZERO. But when the machine is in state A and the leading edge of a pulse appears on the B input, both outputs, Q_a and Q_b, will be HIGH. If this condition can be detected and used to set both devices to ZERO immediately, then state C has been realized. A NAND gate driving the reset inputs of the state A and B networks achieves this operation **(Fig. 5).**

Comparing the workings of this circuit to the final version of the state diagram **(Fig. 6),** you can see that the model has been successfully constructed for all possible input combinations. This state-transition table also indicates all possible input/output combinations, thus assuring that no "locked-up" conditions exist.

The lines labelled "reset" correspond to the NAND gate's resetting flip-flops to ZERO. Out of a possible 16 states (two inputs plus two outputs $= 2^4$), 12 stable conditions exist. Note that the four remaining states (Q_a and Q_b—both HIGH) generate an immediate reset back to a stable state. **Fig. 7** shows the complete frequency/phase comparator and the 3-state charge pump (control-voltage generator).

The digital network used in this realization is only one example of an infinite number of logic-circuit combinations that can be employed. Virtually every major IC manufacturer offers at least one device that will perform the digital function; and many of the phase-locked loop packages available today will use a network satisfying the state-diagram requirements. However, the dual-D version just described is the easiest to understand, since by choosing an edge-triggered type-D flip-flop with negative-going reset, we have eliminated many of the difficulties encountered in determining a circuit by its schematic.

Applying the concept

A practical example should put the concept of a 3-state phase/frequency detector in proper per-

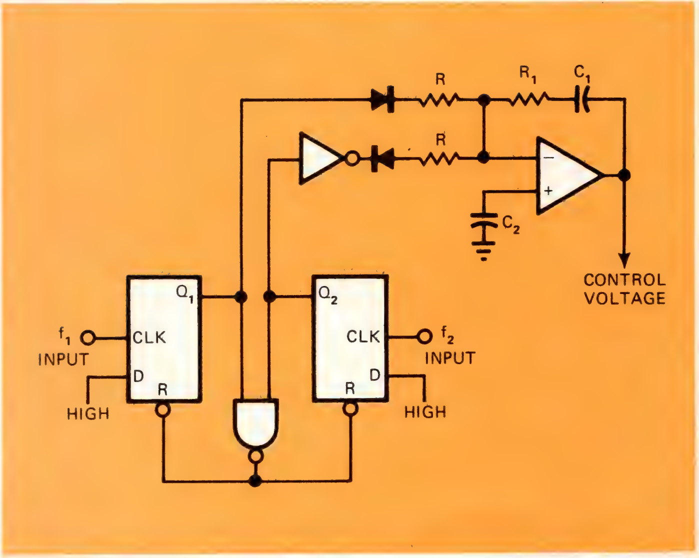
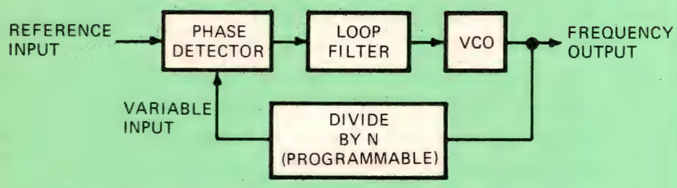


Fig. 7—The completed 3-state phase/frequency detector combines the frequency/phase comparator of **Fig. 5** with **Fig. 1's** contol-voltage generator (tri-state charge pump).

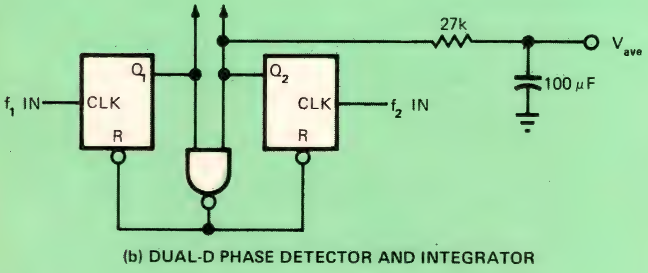
spective. So let's consider the design of a digital frequency synthesizer in which channel change from the low end to the high end of the frequency band occurs by changing the modulus of a programmable divider, **(Fig. 8).**

When the channel change occurs at t = 0, the VCO frequency cannot instantaneously change to the new desired channel, due to the time constant of the system. However, N changes instantaneously, providing the variable input of the phase detector with a sometimes radically different frequency. In fact, it is not unusual for the variable-channel phase-detector input frequency to equal five or 10 times the reference input frequency at t = 0+.

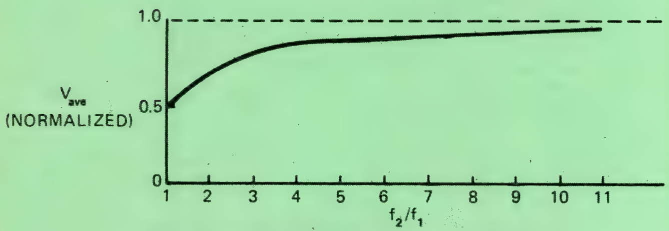
The frequency/phase detector will perform the desired detection to bring the VCO frequency to the new value ($N \times f_{ref}$) by applying pulses on the proper phase-detector output. This will, in effect, incrementally slew the control line to the new voltage. The rate at which the "slew" occurs—hence the time for wide-channel change—depends on the average value of the pulse. Therefore, attention must be given to the average pump voltage (available as a function of frequency) to determine the lock time of the system. **Fig. 8b** shows the normalized characteristic of the dual-D phase detector and the method of measurement (**Fig. 8c**). In the illustrated circuit, V_{ave} (normalized) = $(1 - f_1/2f_2)$—providing the pulses are not harmonically synchronous.



(a) DIGITAL FREQUENCY SYNTHESIZER



(b) DUAL-D PHASE DETECTOR AND INTEGRATOR



(c) DUAL-D PHASE DETECTOR CHARACTERISTICS

Fig. 8—The digital frequency synthesizer (a), one application of 3-state phase detectors, ranges across the frequency band as the modulus of the divider changes. The integrator output **(b)** determines the normalized dual-D phase-detector characteristic **(c).**

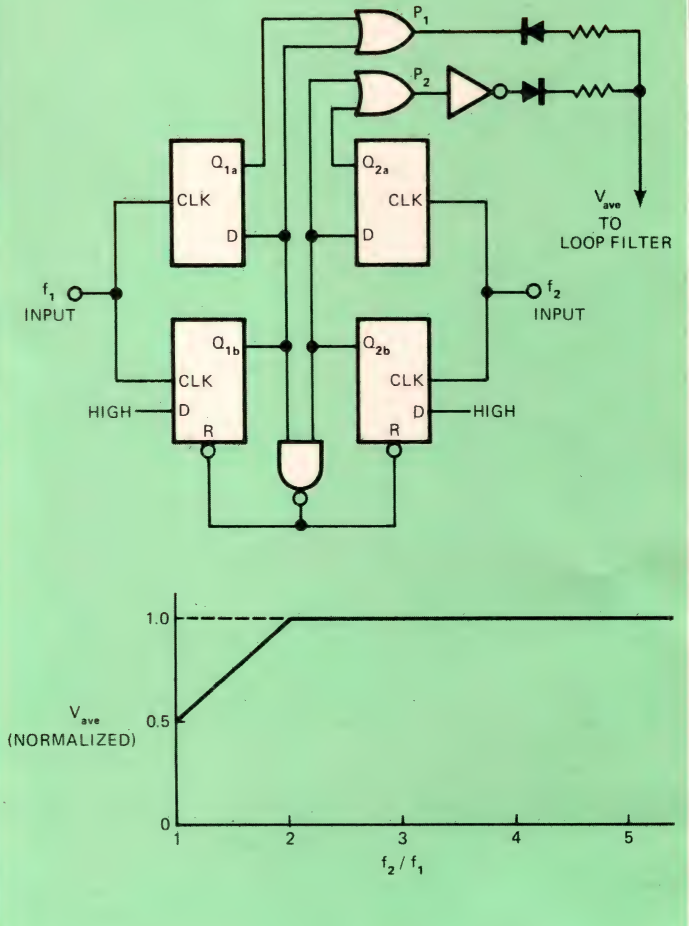


Fig. 9—Quad-D circuit shortens lock time when f_2 is significantly greater than f_1.

Note that when f_2 occurs at a much higher rate than f_1, the output will be HIGH nearly all the time. When f_2 is very slightly greater than f_1, however, the output will be HIGH approximately 50% of the time (over a long interval).

In typical wide-channel change cases where $f_2 = 5f_1$ or $10f_1$, the average voltage will be above 90% of the pulse height. So, for this region, $V_{ave} = V_{pulse\ height}$ is a reasonable approximation. In fact, whenever $f_2 > f_1$ (or vice versa), it is generally useful to assume that $V_{ave} = V_{pulse\ height}$ as a first approximation—and realize that this performance can never be achieved. The actual error will depend on the initial frequency ratio, but magnitudes of 10 or 20% are typical.

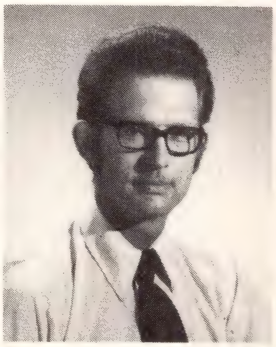
Why not save some "time"?

Fig. 9 shows a configuration that speeds up lock time by clamping the proper output line HIGH when $f_2 = 2f_1 + \epsilon$. This quad-D contains two additional storage elements. In combination with the action of the dual-D configuration, these added elements maintain the proper output HIGH as soon as three consecutive pulses appear on one input between two pulses on the other input.

The quad-D system performs as a normal dual-D for phase detection when alternating pulses are present, and it transitions into the expanded region as f_2 approaches $2f_1$. When $f_2 > 2f_1$, the normalized output voltage is the full pump-pulse height. This results in a much better approximation for calculating lock time when large frequency steps are involved.

Quad-D implementation is such that it is a direct replacement for the dual-D version. Since the phase-detector gain for a phase-locked loop (V/rad) is calculated only when the two input frequencies are identical (differing only in phase), the gain remains the same. For a small maximum channel change where $f_2(\text{max.}) = 1.5f_1$, no noticeable operating difference exists. In systems where $f_2 = 5f_1$ or $10f_1$, however, the quad-D significantly improves lock times, with the magnitude of the improvement depending upon the initial frequency separation. □

Author's biography



C. Andrew Sharpe is a senior engineer at Bendix, Avionics Div., Ft. Lauderdale, FL, where he designs and develops aircraft distance-measuring equipment. He completed his undergraduate studies at North Carolina State and his MSEE at Florida Technological University. Andy holds one patent, with three pending. In his spare time, he enjoys flying and amateur radio.

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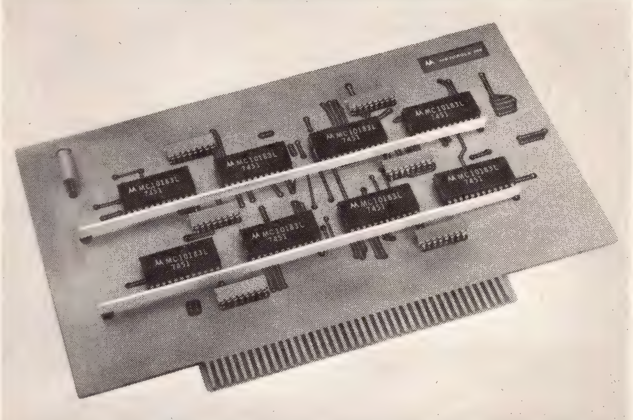

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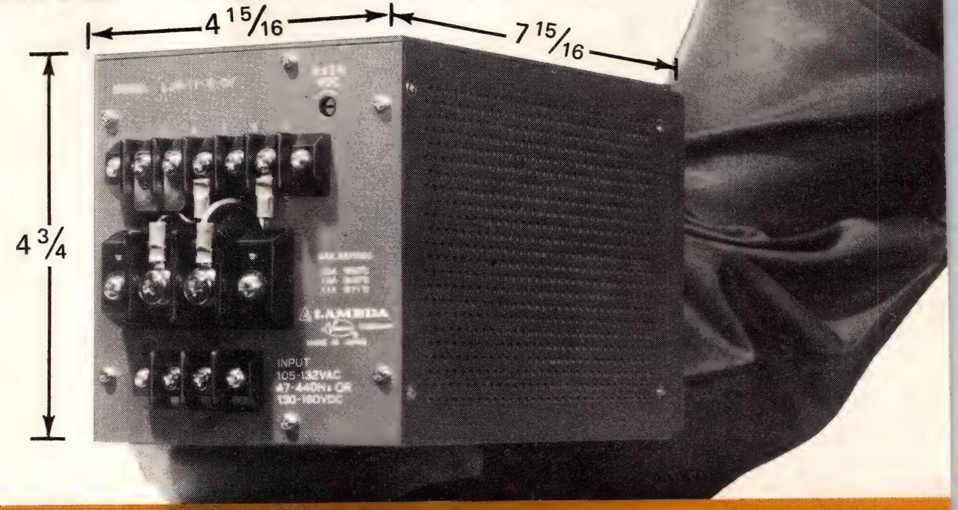

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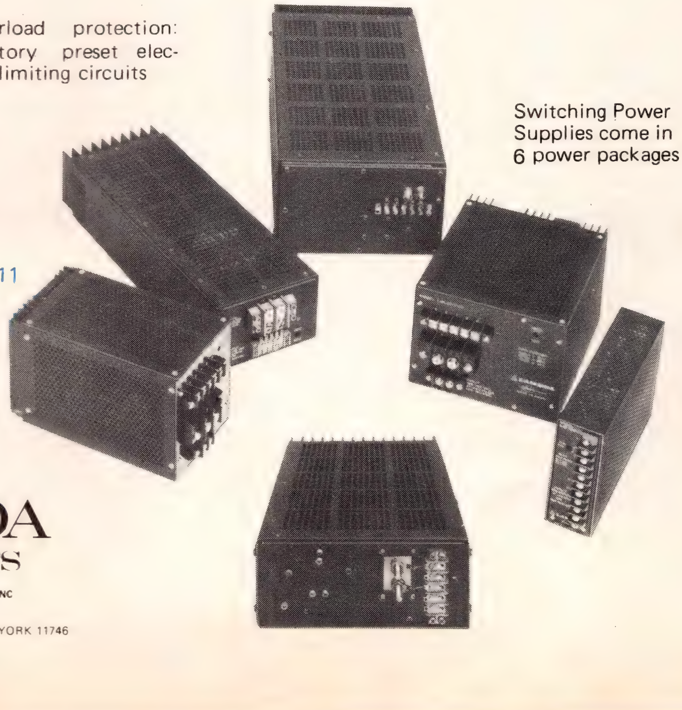

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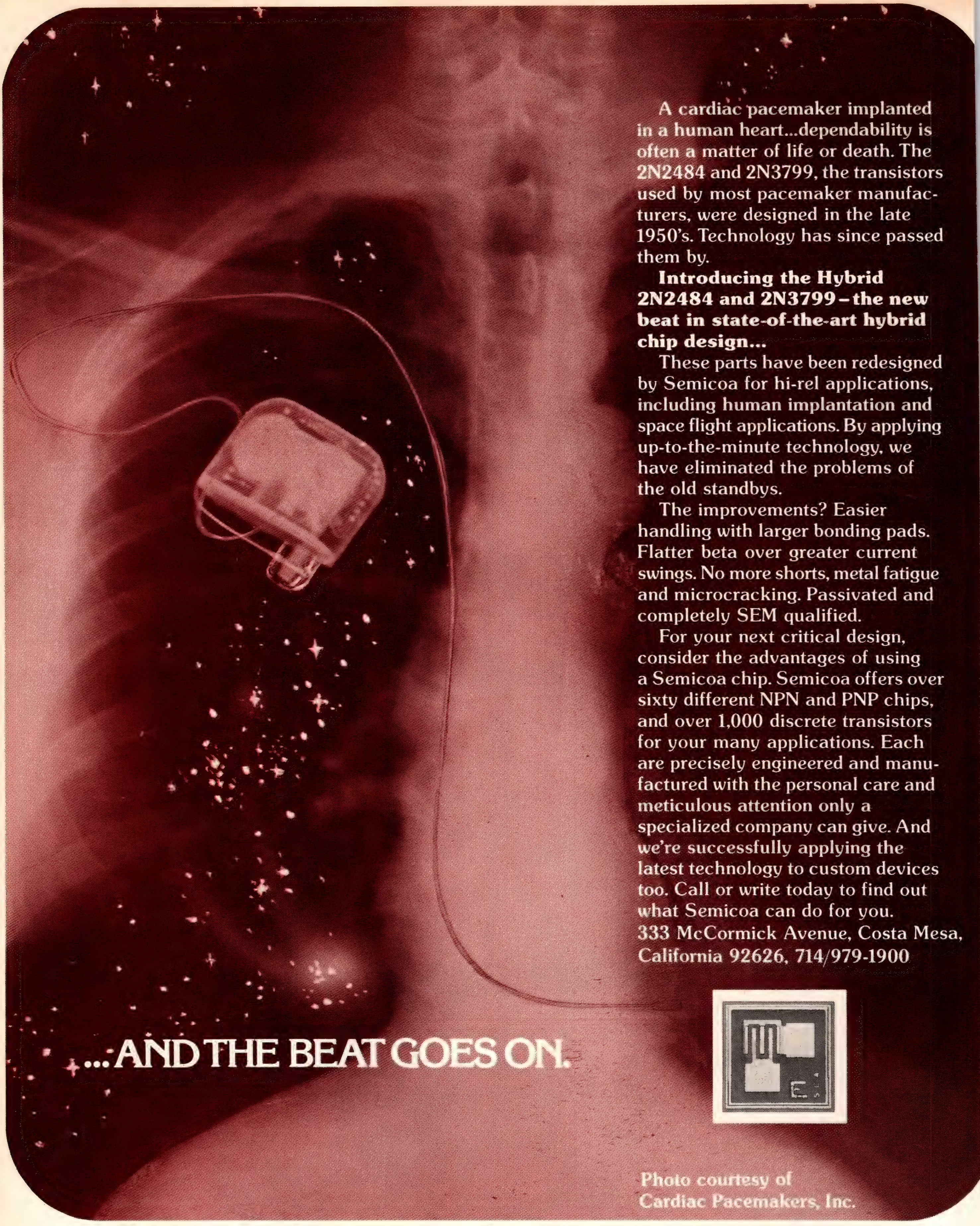

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EDN µP DESIGN SERIES

MONITOR/DEBUGGER saves time when checking µP software

Moving on to the final steps of application program development, its proper execution is evaluated using MONITOR/DEBUGGER programs.

Bruce Gladstone, Microkit, Inc.

Operation of the MONITOR/DEBUGGER will be explained by using it to execute a sample program on our development station hardware. This application program was developed with the aid of the EDITOR in Part 1 of this mini-series (EDN June 20, 1976) and then translated from assembly language into machine language with the ASSEMBLER in Part 2 (EDN September 20, 1976).

Our sample application program, in case you have forgotten, moves a string of ASCII bytes constituting a sentence (ending with a period) from one area of RAM, INBUF, to another area, OUTBUF.

Software tools load automatically

The MONITOR/DEBUGGER program is loaded into the development station in the same fashion as the EDITOR and ASSEMBLER before it **(Fig. 1)**. In my system, this software tool is also stored on its own cassette (cassette-3 according to the

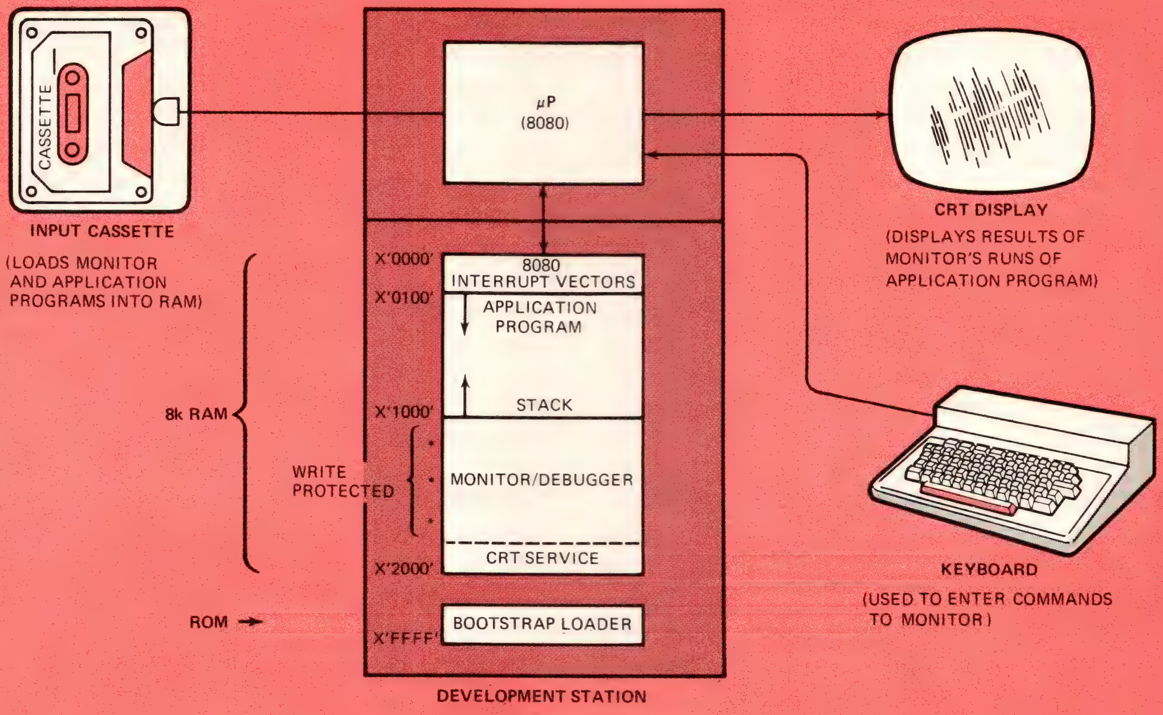


Fig. 1—General-purpose development station is transformed into a "test bed" for running application programs when the MONITOR/DEBUGGER program is loaded in from its cassette (cassette-3). At this stage of the project, mainly application software is being checked out. Though the application program is running on the same basic hardware that will be used in the end application, the configuration of peripheral devices and memory is probably not identical. It's best, however, to first check the application software on hardware that is known to be correct—assuming that the development station is in 100% perfect operating condition—than to have the double confusion of trying to run preliminary software that is full of bugs on breadboard hardware that is similarly full of bugs.

inventory list of cassettes shown in **Table 1**). This cassette is inserted into the input transport and the load button above the keyboard pressed. The development station uses its short 256-byte resident bootstrap-loader program (in firmware or ROM because it will always be needed) to automatically load the 3k-byte MONITOR/DEBUGGER program.

This program informs the bootstrap loader to start loading it at RAM location hex 1000 (or X'1000'). This application program, as illustrated in Part 2, similarly informs the bootstrap loader to start loading it at location hex 100 (or X'100'). That's where the ASSEMBLER set up the initial address in response to the ORG pseudo instruction. We did not mention it in Part 2, but this location was purposely chosen so that the application program would land in an unoccupied region of the development station's memory space and not conflict with regions used by the MONITOR/DEBUGGER, the bootstrap loader or the symbol table (if that were retained from the ASSEMBLER stage). As seen in **Fig. 1**, the MONITOR/DEBUGGER resides into a higher address region of memory space than does the application program.

At the end of a short 30-sec load operation, the general-purpose station has been transformed into a system that can run and modify application programs, as directed by the user through keyboard-entered commands. This system can MONITOR the running of application programs, let the user find the inevitable bugs buried in those programs, and make changes that will DEBUG those bugs.

The application program is then loaded from its cassette (cassette-C) into the development station by the same process. Both loading processes will next automatically direct the respective programs to their proper places in the development-station RAM. The programs in the cassettes carry their own memory location information to prevent conflicts with each other.

Operating features of MONITOR/DEBUGGER

Before trying to execute the application program, we had better discuss some features of the MONITOR/DEBUGGER. What does the display mean? What commands are available? How and when does the user employ them? It's a waste of time to try using a computer-software development package like this without understanding it: One must be able to give it commands that it comprehends.

Don't be overly dismayed by the growing proliferation of EDITORS, ASSEMBLERS and MONITOR/DEBUGGERS now available, each with its own set of commands. Literally hundreds of these software development tools are available on the market (and additional ones pop up with every new μP and μP support system). Fortunately however, most of them have a family resemblance with each other.

The software "designers" who create these tools try to follow terminology patterns of established industry leaders, like IBM and DEC (and now Intel), not unlike having one common-root tongue with many local dialects.

Flow charts show interactive interplay

The flow chart for the MONITOR/DEBUGGER program is shown in **Figs. 2a** and **2b**. **Fig. 2a** flow charts the command-scanner portion of the software, while **Fig. 2b** details the routine for one command, DISPLAY. Quite a similarity is apparent between this flow chart and that for the EDITOR in Part 1: Both programs have a high degree of man-machine interaction. The machine continually shows you its current status and you continually tell it where to go next.

Fig. 2a indicates that the MONITOR/DEBUGGER will respond to 15 user commands. Three, CONTROL-A, CONTROL-B and CONTROL-E, are immediately executed commands and are exceptions to the general requirement that a depression of the CR key is needed as a go-ahead signal. Respectively, they roll the CRT memory display forward eight locations, backward eight locations, and SINGLE-STEP the program.

The flow chart for the DISPLAY command, **Fig. 2b**, is rather simple. The latter must have an argument, for the system must be told what location to display. In my system, this argument is first checked for a "$" character. If the user has typed in a "$", the system recalls the previous location. A one-level stack for the DISPLAY command exists to permit implementation of the "$" recall function by swapping the contents of a location called ADDR with that of one called ADDRS. The ADDR and ADDRS contain present and previous values of the display locations.

If the argument is not a "$", then a routine, PARM, is called to convert the argument into hex form. My MONITOR—in common with many others—allows you to enter an address in either hex or ASCII form (some systems also permit address insertion in decimal form). This system also allows you to key in the address argument as an arithmetic expression that the MONITOR must finish computing.

For example, you can use plus and minus signs to specify relative or offset addresses. This is more helpful than it might seem because the computations, though simple, must be done in hex, which can confuse even highly experienced programmers. You can also specify indirect

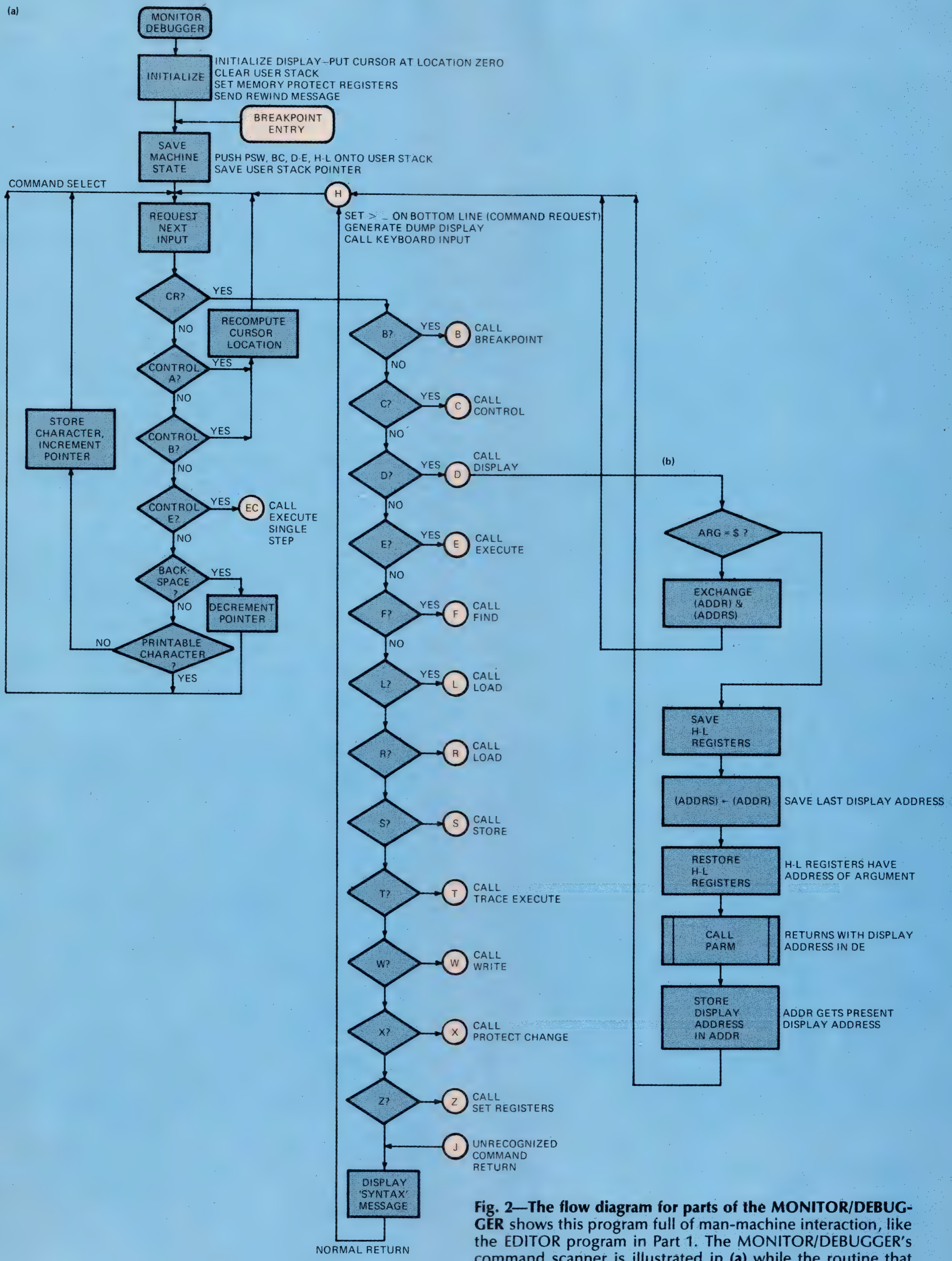


Fig. 2—The flow diagram for parts of the MONITOR/DEBUGGER shows this program full of man-machine interaction, like the EDITOR program in Part 1. The MONITOR/DEBUGGER's command scanner is illustrated in **(a)** while the routine that implements the DISPLAY command is shown in **(b).**

addresses, or type in a symbol (if the ASSEMBLER's label table is either still in RAM or has been read back into RAM). The routine called PARM performs all expression evaluation. *(Ed. Note: A tradeoff occurs in the usefulness of features like this, as they demand that you either learn them by heart or continually break your train of thought to look them up in the supplier's MONITOR/DEBUGGER manual.)*

There's three essential MONITOR commands

A minimum of three basic commands are needed for any debugging task: EXECUTE, DISPLAY and STORE. They will be explained in terms of their sequential use for a typical "run" of the application program.

EXECUTE: Obviously, you need a command to make the development-station μP jump from the MONITOR/DEBUGGER program that it is normally running to the application program and start its execution. In my system, keying in "E" for EXECUTE (invariably the commands in these systems are entered as one- or two-letter abbreviations), with no argument, causes the μP to begin executing the program at the address where the cursor is pointing. The μP in the application station then starts fetching and executing the contents of that memory location.

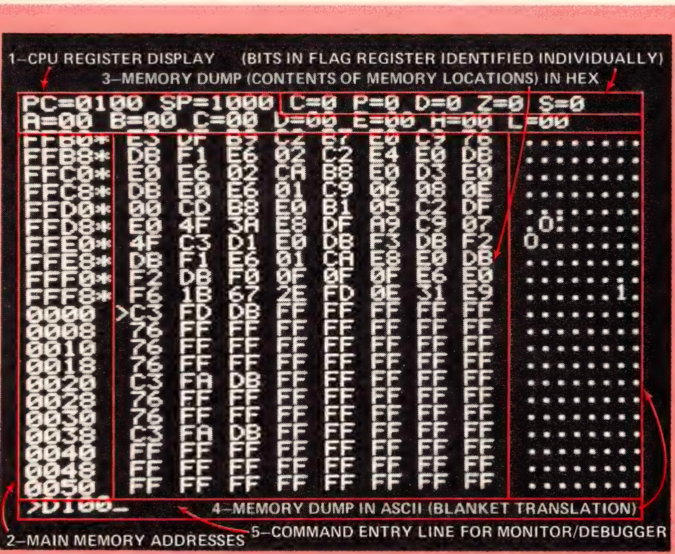
Naturally, for the execution to be meaningful, the program counter (PC) must also point at this same location. Additionally, this location must be the proper first byte of a valid instruction. When an argument follows EXECUTE, the MONITOR/DEBUGGER first evaluates the expression that forms the argument, and then starts executing at the resulting address.

DISPLAY: A command is also required that permits you to select the particular memory byte to be displayed in the central region of the CRT screen. The MONITOR evaluates the argument expression for DISPLAY and places the cursor at that location. As a bonus, it also gives you a dump of adjacent memory locations ahead and behind that location. This is a time-saving feature, for it allows you to confirm the correctness of the exact location you're viewing, or question the contents of adjacent locations.

Decided benefits of the newer CRT displays over previous teletype printouts include greater speed and a much wider "window" through which you can view the insides of LSI chips.

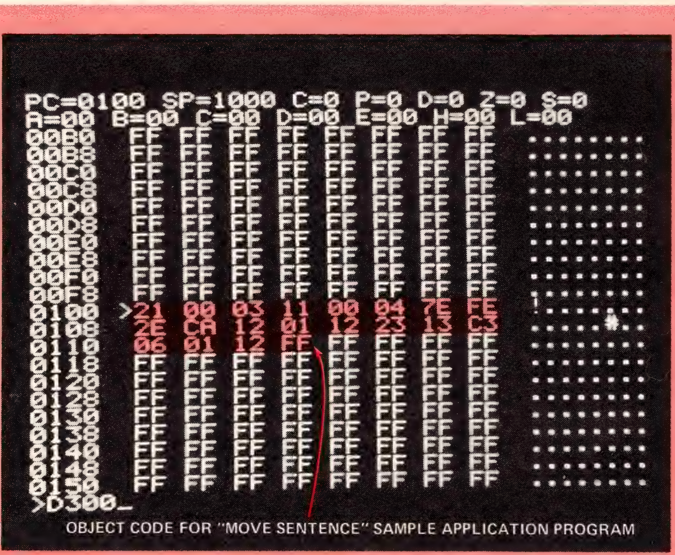
STORE: In order to get the inevitable "bugs" out of an application program, you must be able to make appropriate changes. The STORE command lets you patch in changes quickly—in hexadecimal format in my system (typical with most available μP MONITOR/DEBUGGERS). Thus, you don't have to first reload the EDITOR and then the ASSEMBLER into the development station just to change a few bytes of application code.

You can also use STORE to change any test-case data that was placed into memory for the application program to operate upon (like the ASCII-coded text our sample program stored in INBUF).


1–CPU REGISTER DISPLAY
(BITS IN FLAG REGISTER IDENTIFIED INDIVIDUALLY)
3–MEMORY DUMP (CONTENTS OF MEMORY LOCATIONS) IN HEX
4–MEMORY DUMP IN ASCII (BLANKET TRANSLATION)
5–COMMAND ENTRY LINE FOR MONITOR/DEBUGGER
2–MAIN MEMORY ADDRESSES

```
PC=0100 SP=1000 C=0 P=0 D=0 Z=0 S=0
A=00 B=00 C=00 D=00 E=00 H=00 L=00
FFB0* E3 DF B7 C2 B7 E0 C9 76  ........
FFB8* DB F1 E6 02 C2 E4 E0 DB  ........
FFC0* E0 E6 02 CA B8 E0 D3 E0  ........
FFC8* DB E0 E6 01 C9 06 08 0E  ........
FFD0* 00 CD B8 E0 B1 05 C2 DF  ........
FFD8* E0 4F 3A E8 DF A9 C9 07  .0:.....
FFE0* 4F C3 D1 E0 DB F3 DB F2  0.......
FFE8* DB F1 E6 01 CA E8 E0 DB  ........
FFF0* F2 DB F0 0F 0F 0F E6 E0  ........
FFF8* F6 1B 67 2E FD 0E 31 E9  ......1.
0000 >C3 FD DB FF FF FF FF FF  ........
0008  76 FF FF FF FF FF FF FF  ........
0010  76 FF FF FF FF FF FF FF  ........
0018  76 FF FF FF FF FF FF FF  ........
0020  C3 FA DB FF FF FF FF FF  ........
0028  76 FF FF FF FF FF FF FF  ........
0030  76 FF FF FF FF FF FF FF  ........
0038  C3 FA DB FF FF FF FF FF  ........
0040  FF FF FF FF FF FF FF FF  ........
0048  FF FF FF FF FF FF FF FF  ........
0050  FF FF FF FF FF FF FF FF  ........
>D100_
```

Fig. 3—A complete look inside the μP system's LSI chips, particularly for small application routines like the 21-byte example, is provided on the development station's CRT by the MONITOR/DEBUGGER. The five elements of the display show the user: what is inside the μP CPU itself (element 1); memory addresses being read out (element 2); the contents of those memory locations (elements 3 and 4); and finally the next MONITOR/DEBUGGER command entered by the user (element 5).



```
PC=0100 SP=1000 C=0 P=0 D=0 Z=0 S=0
A=00 B=00 C=00 D=00 E=00 H=00 L=00
00B0  FF FF FF FF FF FF FF FF  ........
00B8  FF FF FF FF FF FF FF FF  ........
00C0  FF FF FF FF FF FF FF FF  ........
00C8  FF FF FF FF FF FF FF FF  ........
00D0  FF FF FF FF FF FF FF FF  ........
00D8  FF FF FF FF FF FF FF FF  ........
00E0  FF FF FF FF FF FF FF FF  ........
00E8  FF FF FF FF FF FF FF FF  ........
00F0  FF FF FF FF FF FF FF FF  ........
00F8  FF FF FF FF FF FF FF FF  ........
0100 >21 00 03 11 00 04 7E FE  !.......
0108  2E CA 12 01 12 23 13 C3  .....*..
0110  06 01 12 FF FF FF FF FF  ........
0118  FF FF FF FF FF FF FF FF  ........
0120  FF FF FF FF FF FF FF FF  ........
0128  FF FF FF FF FF FF FF FF  ........
0130  FF FF FF FF FF FF FF FF  ........
0138  FF FF FF FF FF FF FF FF  ........
0140  FF FF FF FF FF FF FF FF  ........
0148  FF FF FF FF FF FF FF FF  ........
0150  FF FF FF FF FF FF FF FF  ........
>D300_
```

Fig. 4—The user checks that his application's object code was duly entered by asking for location X'100' to be displayed (see element 5, **Fig 3**). The cursor mark at the center of the memory readout guides the user's eye to X'100' and there he sees the start of his 20 bytes of object code.

Advanced commands speed debug procedure

Other MONITOR/DEBUGGER commands in more elaborate and expensive systems give you important additional capabilities. The two most valuable of these are BREAKPOINT and SINGLE-STEPPING. In addition, many advanced MONITOR/DEBUGGERS now on the market have some sort of TRACING ability.

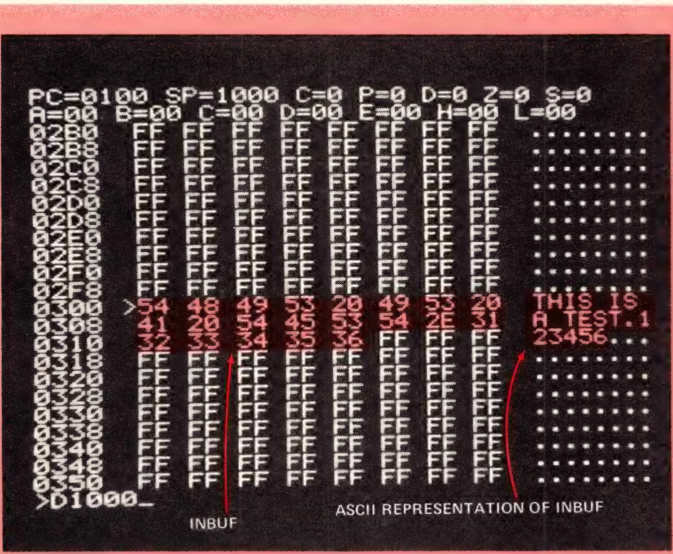
BREAKPOINTS: Being able to set BREAKPOINTS is probably the most powerful debugging capability of all. Instead of simply running the application program straight through from beginning to end, you set BREAKPOINTS at critical junctures. Then the μP will stop when it hits these locations and automatically branch back to the MONITOR/DEBUGGER program. BREAKPOINT can tell you two things about the execution of your application program: First, you can see whether the μP reached that portion of program where the BREAKPOINT was placed (all too often a bug causes the μP to skip over whole routines or hang up in a loop). Second, if the BREAKPOINT is successfully reached, you can then examine at leisure the state of the system at that point.

Typically, BREAKPOINT will be implemented through one of the μP's own interrupts (i.e., via hardware). This way the contents of the CPU registers can be saved in specially assigned memory locations reserved for this purpose before the μP reverts back to executing the MONITOR/DEBUGGER.

You should start off a debugging session by putting BREAKPOINTS between major sections of the application program, an efficient initial approach to checking out a new program. When you know a bug exists somewhere in the program, but have no idea where, a good procedure is to begin by inserting a BREAKPOINT in the middle. The DISPLAY produced by that BREAKPOINT enables you to determine whether the bug is in the first or second half of the program. You can then set another BREAKPOINT in the middle of that half, and further localize the bug down to a quarter of the program. In this manner you continually narrow the bug's location to a manageably short stretch of code. This procedure is analogous to a binary or two-valued search.

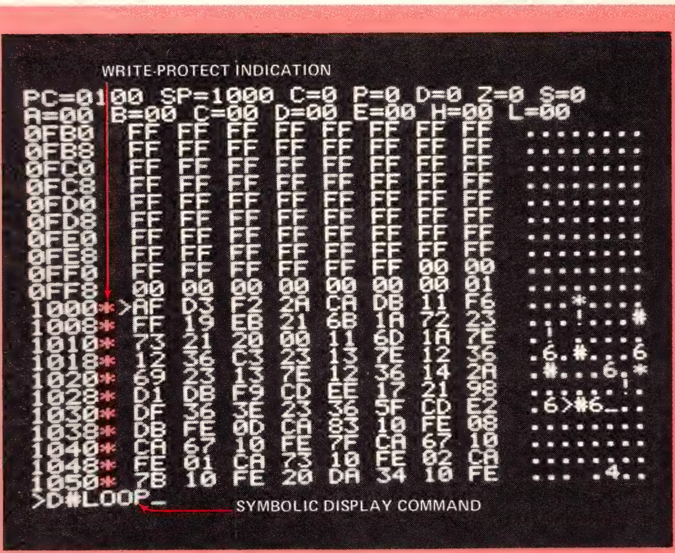
SINGLE-STEPPING: In situations where you have narrowed a bug down to a small area, but it still remains elusive (and for a beginner some of these bugs can be unbelievably so, even when they stare you in the face), it's desirable to switch execution to a SINGLE-STEP mode. Then you can manually step through the sticky region, instruction-by-instruction, and literally watch the PC and other CPU registers in detailed slow-motion action.

SINGLE-STEPPING is, of course, only practical for examining small segments of a program because it takes so long. Even in an application as short as our "move-sentence" example, it takes several tens of seconds to SINGLE-STEP through the complete program because of the multiple traverses of the loop. You will probably step



```
PC=0100 SP=1000 C=0 P=0 D=0 Z=0 S=0
A=00 B=00 C=00 D=00 E=00 H=00 L=00
02B0  FF FF FF FF FF FF FF FF  ........
02B8  FF FF FF FF FF FF FF FF  ........
02C0  FF FF FF FF FF FF FF FF  ........
02C8  FF FF FF FF FF FF FF FF  ........
02D0  FF FF FF FF FF FF FF FF  ........
02D8  FF FF FF FF FF FF FF FF  ........
02E0  FF FF FF FF FF FF FF FF  ........
02E8  FF FF FF FF FF FF FF FF  ........
02F0  FF FF FF FF FF FF FF FF  ........
02F8  FF FF FF FF FF FF FF FF  ........
0300 >54 48 49 53 20 49 53 20  THIS IS 
0308  41 20 54 45 53 54 2E 31  A TEST.1
0310  32 33 34 35 36 FF FF FF  23456...
0318  FF FF FF FF FF FF FF FF  ........
0320  FF FF FF FF FF FF FF FF  ........
0328  FF FF FF FF FF FF FF FF  ........
0330  FF FF FF FF FF FF FF FF  ........
0338  FF FF FF FF FF FF FF FF  ........
0340  FF FF FF FF FF FF FF FF  ........
0348  FF FF FF FF FF FF FF FF  ........
0350  FF FF FF FF FF FF FF FF  ........
>D1000_
```

Fig. 5—Looking at the INBUF region of RAM, the user checks whether it is properly filled with the text data that he will need to exercise his application program. By calling up location X'300' to be displayed, he now has the data in ASCII form (element 4 over in the right-hand side of the CRT readout). This auxiliary ASCII interpretation is useful because the English text can be read directly off the CRT screen.



```
PC=0100 SP=1000 C=0 P=0 D=0 Z=0 S=0
A=00 B=00 C=00 D=00 E=00 H=00 L=00
0FB0  FF FF FF FF FF FF FF FF  ........
0FB8  FF FF FF FF FF FF FF FF  ........
0FC0  FF FF FF FF FF FF FF FF  ........
0FC8  FF FF FF FF FF FF FF FF  ........
0FD0  FF FF FF FF FF FF FF FF  ........
0FD8  FF FF FF FF FF FF FF FF  ........
0FE0  FF FF FF FF FF FF FF FF  ........
0FE8  FF FF FF FF FF FF FF FF  ........
0FF0  FF FF FF FF FF FF 00 00  ........
0FF8  00 00 00 00 00 00 00 01  ........
1000*>AF D3 F2 2A CA DB 11 F6  ...*....
1008* FF 19 EB 21 6B 1A 72 23  ...!...#
1010* 73 21 20 00 11 6D 1A 7E  .! .....
1018* 12 36 C3 23 13 7E 12 36  .6.#...6
1020* 69 23 13 7E 12 36 14 2A  .#...6.*
1028* D1 DB F9 CD EE 17 21 98  ......!.
1030* DF 36 3E 23 36 5F CD E2  .6>#6_..
1038* DB FE 0D CA 83 10 FE 08  ........
1040* CA 67 10 FE 7F CA 67 10  ........
1048* FE 01 CA 73 10 FE 02 CA  ........
1050* 7B 10 FE 20 DA 34 10 FE  ... .4..
>D#LOOP_
```

Fig. 6—Areas of memory not available to the user are flagged by special markers. If he accidentally asks for a display of the RAM region that contains one of the system software tools or system utilities, the display will automatically alert him by placing memory-protect markers by these addresses (the asterisks). Here the user is looking at the first locations of the MONITOR/DEBUGGER itself. In RAM-based development systems, the software tools must be so protected—otherwise they will most likely get wiped out by application programs that go astray.

through the segment several times, first to pick up the patterns of change in registers and memory locations of interest, and then to analyze whether those patterns make logical sense.

TRACING: If the development system can make TRACES, you can return after the fact and look at events that led up to the BREAKPOINT. In the TRACE mode, the MONITOR/DEBUGGER stops program execution after each step and STORES the CPU registers' states at that step. This slows execution a bit from full μP operating speed, but has little detrimental effect at this stage of program development. (It might make a difference, however, when you interconnect the development station to the actual end-product breadboard, especially if the system is supposed to be interacting with external equipment in real time.)

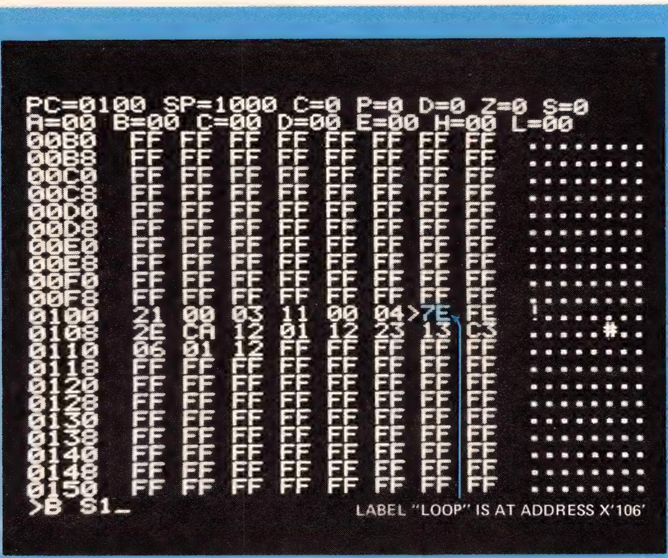
The MONITOR/DEBUGGER continuously pushes these saved values from each step onto a hardware-save stack, thus the number of past steps saved depends on the depth of that stack. This system saves the values from the last 20 steps. Some MONITOR/DEBUGGERS save up to several hundred past steps, but trade off the number of register values saved at each step. However, I believe that it's more important to have the values of all CPU registers available at each step. You rarely know exactly what information you'll need beforehand; you're often looking for a pattern that may exist between several registers. Again, an advantage of CRT displays is that they present an instant panoramic view of the history of the system's operation. You will not, however, have the complete file of hard-copy records that TTY's bang out so generously. These are useful for checking a previous day's runs.

CRT tells all, if you know what it says

Next on the list of priorities is understanding the CRT display. **Fig. 3** shows a typical display in this system consisting of five different elements. This particular display is presented after loading both the MONITOR/DEBUGGER and sample application program, but before entering any commands.

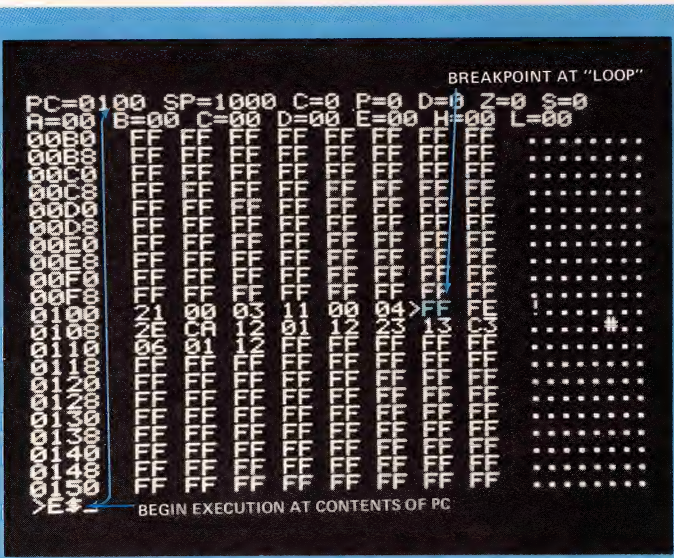
The top element is a dump or readout of the CPU registers. These include the program counter (PC), stack pointer (SP), flag register (F), accumulator (A), and the six general-purpose register pairs (B and C), (D and E) and (H and L). The alert reader may ask, "Since the one lone μP in this development station must alternately run both the MONITOR/DEUBGGER and the application program, won't the registers sometimes reflect the operation of the MONITOR/DEBUGGER program rather than the application program?" The answer is that register values are only taken from the application program at the time it is interrupted by BREAKPOINTS.

In **Fig. 3**, the values represent initial conditions, for no execution of the application program has occurred at this point. The PC has been initialized to X'100', the SP to X'1000' and everything else to zero. When the application program is first executed, these will be the values jammed into the respective CPU registers. The value X'100' for



```
PC=0100  SP=1000  C=0  P=0  D=0  Z=0  S=0
A=00  B=00  C=00  D=00  E=00  H=00  L=00
00B0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00B8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00C0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00C8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00D0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00D8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00E0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00E8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00F0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00F8    FF  FF  FF  FF  FF  FF  FF  FF    ........
0100    21  00  03  11  00  04 >7E  FE    !.......
0108    2E  CA  12  01  12  23  13  C3    .....#..
0110    06  01  12  FF  FF  FF  FF  FF    ........
0118    FF  FF  FF  FF  FF  FF  FF  FF    ........
0120    FF  FF  FF  FF  FF  FF  FF  FF    ........
0128    FF  FF  FF  FF  FF  FF  FF  FF    ........
0130    FF  FF  FF  FF  FF  FF  FF  FF    ........
0138    FF  FF  FF  FF  FF  FF  FF  FF    ........
0140    FF  FF  FF  FF  FF  FF  FF  FF    ........
0148    FF  FF  FF  FF  FF  FF  FF  FF    ........
0150    FF  FF  FF  FF  FF  FF  FF  FF    ........
>B S1_
```

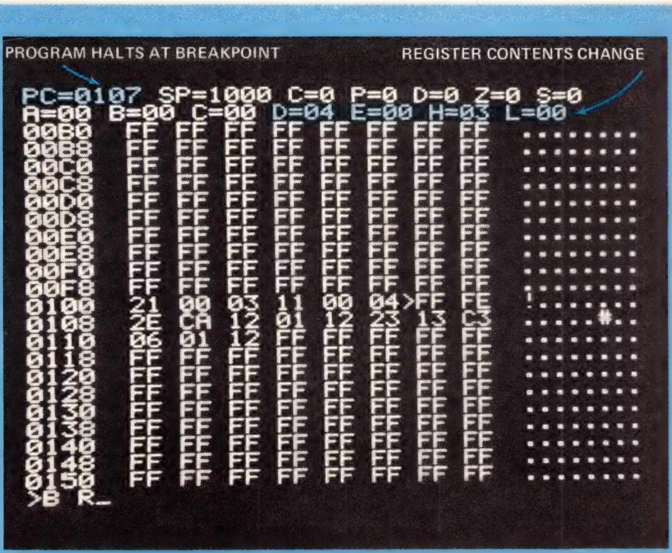
Fig. 7—Here the user has asked for the location of the symbol LOOP to be displayed (cursor points at X'106'). In this system, memory readouts are always lined up in 8-byte groups so the user can quickly orient himself. The bottom line on the screen shows that the user has entered a "B", or BREAKPOINT command. This sets the first of the system's four possible BREAKPOINTS (S1) at the X'106' location where the cursor is pointing.



```
PC=0100  SP=1000  C=0  P=0  D=0  Z=0  S=0
A=00  B=00  C=00  D=00  E=00  H=00  L=00
00B0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00B8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00C0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00C8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00D0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00D8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00E0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00E8    FF  FF  FF  FF  FF  FF  FF  FF    ........
00F0    FF  FF  FF  FF  FF  FF  FF  FF    ........
00F8    FF  FF  FF  FF  FF  FF  FF  FF    ........
0100    21  00  03  11  00  04 >FF  FE    !.......
0108    2E  CA  12  01  12  23  13  C3    .....#..
0110    06  01  12  FF  FF  FF  FF  FF    ........
0118    FF  FF  FF  FF  FF  FF  FF  FF    ........
0120    FF  FF  FF  FF  FF  FF  FF  FF    ........
0128    FF  FF  FF  FF  FF  FF  FF  FF    ........
0130    FF  FF  FF  FF  FF  FF  FF  FF    ........
0138    FF  FF  FF  FF  FF  FF  FF  FF    ........
0140    FF  FF  FF  FF  FF  FF  FF  FF    ........
0148    FF  FF  FF  FF  FF  FF  FF  FF    ........
0150    FF  FF  FF  FF  FF  FF  FF  FF    ........
>E$_
```

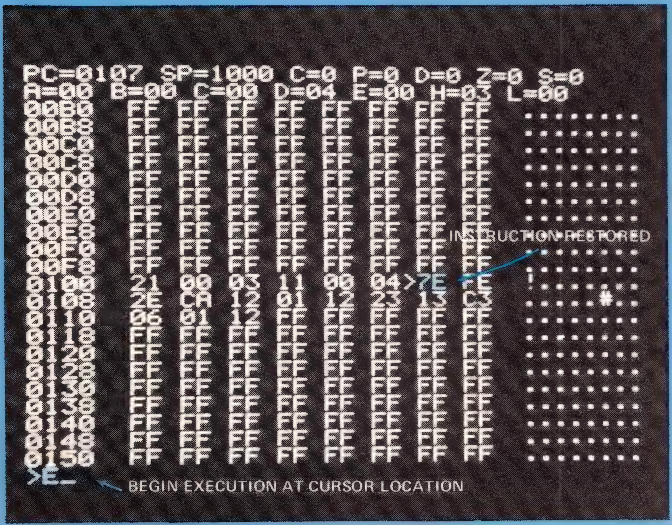
Fig. 8—The user knows that his BREAKPOINT has been set because the FF code for the 8080's software breakpoint instruction, RST-7, appears at location X'106'. He then enters the command E$ which tells the system to start EXECUTING at the address given by the current contents of the PC, or X'100'.

the PC was set back in Part 2 by the ASSEMBLER and loaded along with the object code from cassette-C. The last instruction in that application program was one with the argument MOVE. MOVE, in turn, referenced the label in the symbol table (whose value was X'100') that told the MONITOR/DEBUGGER where to start executing the application program. Initialization of the PC to X'100' represented the MONITOR/DEBUGGER carrying out that order. Thus it was possible to preset commands for the MONITOR/DEBUGGER execution of the application program back at the ASSEMBLER stage.



```
PC=0107 SP=1000 C=0 P=0 D=0 Z=0 S=0
A=00 B=00 C=00 D=04 E=00 H=03 L=00
00B0   FF FF FF FF FF FF FF FF    ........
00B8   FF FF FF FF FF FF FF FF    ........
00C0   FF FF FF FF FF FF FF FF    ........
00C8   FF FF FF FF FF FF FF FF    ........
00D0   FF FF FF FF FF FF FF FF    ........
00D8   FF FF FF FF FF FF FF FF    ........
00E0   FF FF FF FF FF FF FF FF    ........
00E8   FF FF FF FF FF FF FF FF    ........
00F0   FF FF FF FF FF FF FF FF    ........
00F8   FF FF FF FF FF FF FF FF    ........
0100   21 00 03 11 00 04>FF FE    !.......
0108   2E CA 12 01 12 23 13 C3    .....#..
0110   06 01 12 FF FF FF FF FF    ........
0118   FF FF FF FF FF FF FF FF    ........
0120   FF FF FF FF FF FF FF FF    ........
0128   FF FF FF FF FF FF FF FF    ........
0130   FF FF FF FF FF FF FF FF    ........
0138   FF FF FF FF FF FF FF FF    ........
0140   FF FF FF FF FF FF FF FF    ........
0148   FF FF FF FF FF FF FF FF    ........
0150   FF FF FF FF FF FF FF FF    ........
>B R_
```

Fig. 9—EXECUTION of the application program has halted at the BREAKPOINT, indicated by PC reading X'107', one location beyond the BREAKPOINT set in **Fig. 8.** The user can now see whether proper initialization occurred by examining the contents of CPU register pairs D-E and H-L. It did because they contain 0400 and 0300. Satisfied, the user resets the BREAKPOINT by the command BR and, as seen in the next illustration, the proper application code is returned to location X'106'.



```
PC=0107 SP=1000 C=0 P=0 D=0 Z=0 S=0
A=00 B=00 C=00 D=04 E=00 H=03 L=00
00B0   FF FF FF FF FF FF FF FF    ........
00B8   FF FF FF FF FF FF FF FF    ........
00C0   FF FF FF FF FF FF FF FF    ........
00C8   FF FF FF FF FF FF FF FF    ........
00D0   FF FF FF FF FF FF FF FF    ........
00D8   FF FF FF FF FF FF FF FF    ........
00E0   FF FF FF FF FF FF FF FF    ........
00E8   FF FF FF FF FF FF FF FF    ........
00F0   FF FF FF FF FF FF FF FF    ........
00F8   FF FF FF FF FF FF FF FF    ........
0100   21 00 03 11 00 04>7E FE    !.......
0108   2E CA 12 01 12 23 13 C3    .....#..
0110   06 01 12 FF FF FF FF FF    ........
0118   FF FF FF FF FF FF FF FF    ........
0120   FF FF FF FF FF FF FF FF    ........
0128   FF FF FF FF FF FF FF FF    ........
0130   FF FF FF FF FF FF FF FF    ........
0138   FF FF FF FF FF FF FF FF    ........
0140   FF FF FF FF FF FF FF FF    ........
0148   FF FF FF FF FF FF FF FF    ........
0150   FF FF FF FF FF FF FF FF    ........
>E_
```

Fig. 10—The user can continue EXECUTION of the application program now that the proper application code is back in location X'106'. He enters "E" without an argument to command the continuation (see **Fig. 11).**

Another such advance setting of a MONITOR/DEBUGGER command was the insertion of the RST-7 instruction at line 113. This will now be used to stop the execution of the application program and send control back to the MONITOR/DEBUGGER. The RST-7 instruction could have been left out for insertion during the MONITOR/DEBUGGER runs, but since you know you will always want a stop at this point, it makes sense to insert it while in the ASSEMBLER mode. Of course, these types of instructions would not be retained in the final product's program.

The SP is also initialized during the MONITOR/DEBUGGER loading processor and points at location X'1000' which is the top of the user area in the development station's RAM. The SP should be as high in memory as possible because the stack will grow downwards when bytes are pushed onto it.

The 21 lines in the center of the CRT display, elements 2, 3 and 4 in **Fig. 3**, represent a main memory dump. Along the left-hand edge (element 2), are main memory location addresses in hexadecimal notation. They apply to the first location in each line and are spaced eight locations apart. In the center of the screen (element 3) are eight columns showing the contents of these locations, also in hex form. The leftmost column is the address given for that line.

Along the right-hand side of the screen (element 4) the eight columns of data are repeated, but this time translated to ASCII characters. There is nothing selective about which bytes are converted to ASCII; any value between hex 20 and 60 (the standard 64-character ASCII set) is routinely converted. Nevertheless, users find they can scan this section of the display and quickly pick out what they are looking for.

In **Fig. 3**, the display has been initialized to location zero, pointed out by the ">" character used as the cursor. The contents of the zero location happen to be "C3", the beginning of a JUMP instruction used by the MONITOR/DEBUGGER. FD and DB, located at one and two, make up the DBFD location to which the JUMP will be made.

The 8080's reset signal now causes it to fetch the first instruction from location X'100'. JUMP at this location will then vector the 8080 into the MONITOR/DEBUGGER.

In much the same way as with the EDITOR, the cursor character is the visual pointer that tells you where you are in the program. Also displayed are 80 locations on each side of the cursor. You might wonder, in this case, what is displayed above the cursor, which is pointing to location zero (C3). This is, in fact, the very top of memory space where the first lines of the 256-byte loader program reside.

At the very bottom of the CRT display (element 5) is the MONITOR/DEBUGGER's command-entry line, as it was for the EDITOR. A common feature found in this type of man-machine system is for the machine to echo your input command as you keyboard it in, but not execute it until you give the go-ahead, typically by pressing the CR key. This lets you correct entries before they are executed.

Debugging the sample application program

Now that we have explained the main features of the MONITOR/DEBUGGER, we are ready to use this tool to check out our sample application program. The illustrations from **Fig. 3** onward give a running history of what the MONITOR/DEBUGGER CRT display will look like as we do this. With these illustrations, you can follow the debugging progress almost as if you were in front of the development station itself.

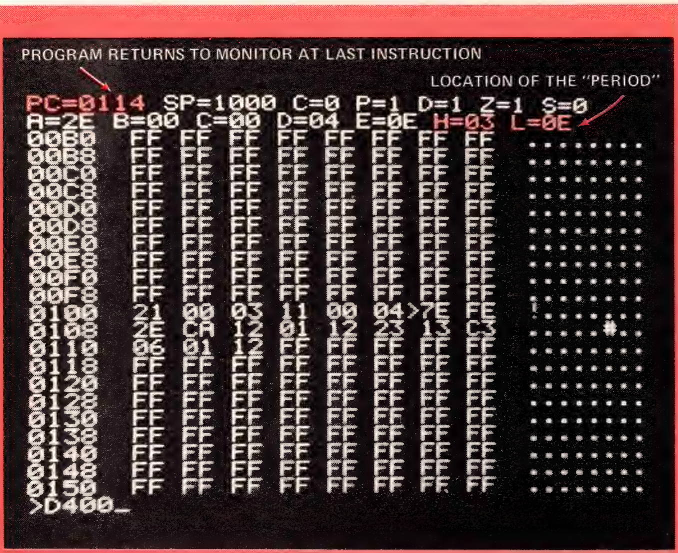
As with the EDITOR, the command entered on the command-entry line at the bottom of the display in one illustration will produce the results seen in the following one. For example, in **Fig. 3** the command D100, the shorthand abbreviation for "DISPLAY location 100," has been entered. Then in **Fig. 4**, results of the MONITOR/DEBUGGER carrying out this command appear on the screen. The contents of the 168 bytes of memory with location 100 in the center is displayed with the display cursor pointing at the requested location, X'0100' (hex notation).

The user requested a display of location X'0100' to check that his application program is entered in the development-station memory. The application program is there, as **Fig. 4** shows, from locations X'0100' to X'0113' in its final object-code form as generated by the ASSEMBLER in Part 2.

Next, the user will key in the D300 command (shown at the bottom of **Fig. 4)** to check that INBUF contains the sample text to be used when trying out the application program. And in **Fig. 5,** you can see that INBUF has been properly entered. Here, you can also look to the right-hand ASCII representation, because it is naturally easier to understand.

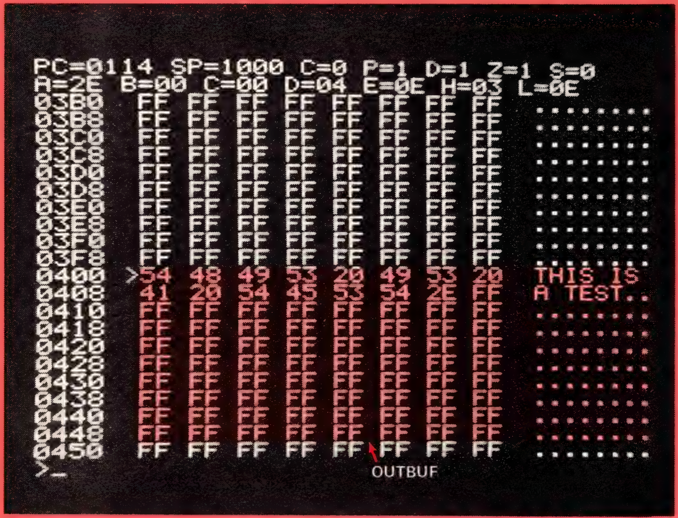
Now suppose the user is not too familiar with this particular system and wants to see if a certain region of memory is free to use. He then keys in D1000 to display that region (D1000 is entered at the bottom of **Fig. 5).** In **Fig. 6** you quickly see that at X'1000' he runs out of free RAM and into a protected area (asterisks alongside the address column to the left of the CRT display indicate protected and unavailable locations). This system achieves such protection through a combination of hardware and software techniques. Most systems that put their software tools in RAM (rather than ROM) find it essential to provide such protection.

Now to quickly return the display to his application program, the user types in D#LOOP (bottom of **Fig. 6**). He is taking advantage of the fact that the symbol table, generated during the ASSEMBLER processing of Part 2, is still in the



```
PC=0114 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=2E B=00 C=00 D=04 E=0E H=03 L=0E
00B0   FF FF FF FF FF FF FF FF    ........
00B8   FF FF FF FF FF FF FF FF    ........
00C0   FF FF FF FF FF FF FF FF    ........
00C8   FF FF FF FF FF FF FF FF    ........
00D0   FF FF FF FF FF FF FF FF    ........
00D8   FF FF FF FF FF FF FF FF    ........
00E0   FF FF FF FF FF FF FF FF    ........
00E8   FF FF FF FF FF FF FF FF    ........
00F0   FF FF FF FF FF FF FF FF    ........
00F8   FF FF FF FF FF FF FF FF    ........
0100   21 00 03 11 00 04>7E FE    !.......
0108   2E CA 12 01 12 23 13 C3    .....#..
0110   06 01 12 FF FF FF FF FF    ........
0118   FF FF FF FF FF FF FF FF    ........
0120   FF FF FF FF FF FF FF FF    ........
0128   FF FF FF FF FF FF FF FF    ........
0130   FF FF FF FF FF FF FF FF    ........
0138   FF FF FF FF FF FF FF FF    ........
0140   FF FF FF FF FF FF FF FF    ........
0148   FF FF FF FF FF FF FF FF    ........
0150   FF FF FF FF FF FF FF FF    ........
>D400_
```

Fig. 11—The system completes the EXECUTION of the sample program. PC is now 0114, pointing at one location beyond the RST-7 instruction that terminates EXECUTION at the end of the program. The accumulator (A) contains the 2E value used in the comparison that determined when the ASCII code for a period was reached in the string of text data brought in from INBUF. D-E and H-L pointers have incremented to X'040E' and X'030E' respectively, for they were indexed 15 times in the process of getting to the ASCII period in INBUF. Note also that the flags at the top of the CRT display have been altered by the program execution.



```
PC=0114 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=2E B=00 C=00 D=04 E=0E H=03 L=0E
03B0   FF FF FF FF FF FF FF FF    ........
03B8   FF FF FF FF FF FF FF FF    ........
03C0   FF FF FF FF FF FF FF FF    ........
03C8   FF FF FF FF FF FF FF FF    ........
03D0   FF FF FF FF FF FF FF FF    ........
03D8   FF FF FF FF FF FF FF FF    ........
03E0   FF FF FF FF FF FF FF FF    ........
03E8   FF FF FF FF FF FF FF FF    ........
03F0   FF FF FF FF FF FF FF FF    ........
03F8   FF FF FF FF FF FF FF FF    ........
0400  >54 48 49 53 20 49 53 20    THIS IS 
0408   41 20 54 45 53 54 2E FF    A TEST..
0410   FF FF FF FF FF FF FF FF    ........
0418   FF FF FF FF FF FF FF FF    ........
0420   FF FF FF FF FF FF FF FF    ........
0428   FF FF FF FF FF FF FF FF    ........
0430   FF FF FF FF FF FF FF FF    ........
0438   FF FF FF FF FF FF FF FF    ........
0440   FF FF FF FF FF FF FF FF    ........
0448   FF FF FF FF FF FF FF FF    ........
0450   FF FF FF FF FF FF FF FF    ........
>_
```

Fig. 12—Calling up a DISPLAY of OUTBUF at X'0400' is a final check that EXECUTION of the application has been fully carried out. The ASCII representation to the right shows that the sentence has been moved. Compare OUTBUF with INBUF back in **Fig. 5** to see that the characters following the period were not moved.

development station's memory. He only has to remember the label LOOP to recall that part of the program. (He should remember LOOP because it was one of the nicknames he created to describe a part of his program.)

Fig. 7 shows how this symbolic address, LOOP, gets the application program back on the CRT screen. Note that the cursor is now pointing at location X'106', the symbol value for LOOP. The user decides to set a BREAKPOINT here for his first run of the application program. This BREAKPOINT allows him to see if the first two initialization instructions of the application program produce the desired setups of CPU pointer registers.

B S1, keyed in at the bottom of **Fig. 7,** shows how he enters the BREAKPOINT command. The B is shorthand for BREAKPOINT and the S1 means BREAKPOINT #1 has been set (up to four BREAKPOINTS can be set at one time in this system). No argument is needed because the MONITOR/DEBUGGER puts the BREAKPOINT where the cursor is pointing.

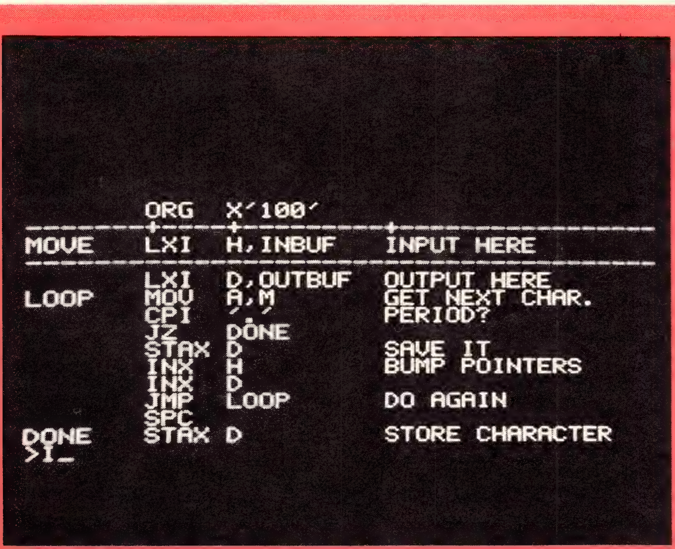
Fig. 8 shows that the BREAKPOINT command caused the 7E in location 106 to be replaced with FF. The FF code is the 8080's RST-7 or software interrupt instruction. It causes the 8080 to jump to location X'38' (as shown in **Fig. 3)** where the JUMP (code C3) to location DBFE occurs. This is in the MONITOR/DEBUGGER program, thus the FF code causes an unconditional jump out of the application program and into the MONITOR/DEBUGGER program.

The user enters the E$, shown at the bottom of **Fig. 8,** to EXECUTE the application program. The "$" argument requests that this EXECUTION begin where the PC is currently pointing; in this instance at location X'100' which happens to be the start of the application program. **Fig. 9** shows that the EXECUTION got as far as the BREAKPOINT at location X'106' before reverting back to the MONITOR/DEBUGGER and producing the display show. The PC is X'107', one location beyond the 106 BREAKPOINT which is where it should be.

You can see by the contents of CPU register pairs D-E and H-L at the top of the CRT display that the first two instructions of the application program (first six bytes) did produce the proper initialization. Pair D-E contains 400 and pair H-L contains 300, so they are properly set up to point to the beginning locations of OUTBUF and INBUF, respectively.

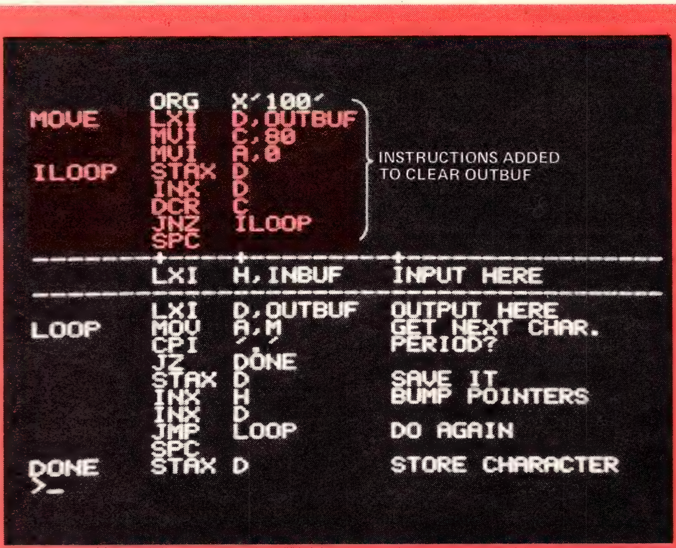
Satisfied that initialization is correct, the user removes the BREAKPOINT from location X'106' with the BREAKPOINT RESET (BR) command entry **(Fig. 9). Fig. 10** shows the program restored to its original form. *(Ed. Note: Author Gladstone is of the opinion that normally the user will only want to set one BREAKPOINT at a time. Although his system permits up to four BREAKPOINTS to be set simultaneously, Gladstone feels that most users will find it difficult to keep track of what they are doing if they set multiple breakpoints. Thus, the BR command resets all BREAKPOINTS.)*

For the program to run to completion, the user enters just "E" (EXECUTE without an argument) **(Fig. 10).** Program EXECUTION starts at 106 where the cursor is pointing and continues to 113 where it is stopped by the FF code (RST-7 instruction) that was put in for that purpose back in Part 2. **Fig. 11** displays the results of this first complete run of



```
        ORG   X´100´
--------+-----+-----------+------------------
MOVE    LXI   H,INBUF     INPUT HERE
---------------------------------------------
        LXI   D,OUTBUF    OUTPUT HERE
LOOP    MOV   A,M         GET NEXT CHAR.
        CPI   ´.´         PERIOD?
        JZ    DONE
        STAX  D           SAVE IT
        INX   H           BUMP POINTERS
        INX   D
        JMP   LOOP        DO AGAIN
        SPC
DONE    STAX  D           STORE CHARACTER
>I_
```

Fig. 13—The EDITOR has been reloaded into the development station and the application source program read back from cassette-B.



```
        ORG   X´100´
MOVE    LXI   D,OUTBUF
        MVI   C,80
        MVI   A,0
ILOOP   STAX  D
        INX   D
        DCR   C
        JNZ   ILOOP
        SPC
--------+-----+-----------+------------------
        LXI   H,INBUF     INPUT HERE
---------------------------------------------
        LXI   D,OUTBUF    OUTPUT HERE
LOOP    MOV   A,M         GET NEXT CHAR.
        CPI   ´.´         PERIOD?
        JZ    DONE
        STAX  D           SAVE IT
        INX   H           BUMP POINTERS
        INX   D
        JMP   LOOP        DO AGAIN
        SPC
DONE    STAX  D           STORE CHARACTER
>_
```

Fig. 14—New instructions to pre-clear OUTBUF are added with the aid of the EDITOR. This little routine first loads a zero into the accumulator (A) and then stores this into OUTBUF.

the application program.

PC is now at 114, or one beyond the final RST-7 instruction. The accumulator (A) contains 2E, which is the hex value for the ASCII period that lets the program know when it has reached the end of the text sentence in INBUF. The D-E register pair contains X'040E' and the H-L register pair contains X'030E'. This indicates how far they were indexed as they addressed OUTBUF and INBUF until the period was found. Note how the flags have been altered.

As a final check upon this program's execution, the user asks for a display of OUTBUF. You can see in **Fig. 12** the sentence has been moved, up to and including the period (though in this system it is difficult to distinguish periods, as the same character is used to represent non-ASCII bytes too).

Improving the application program

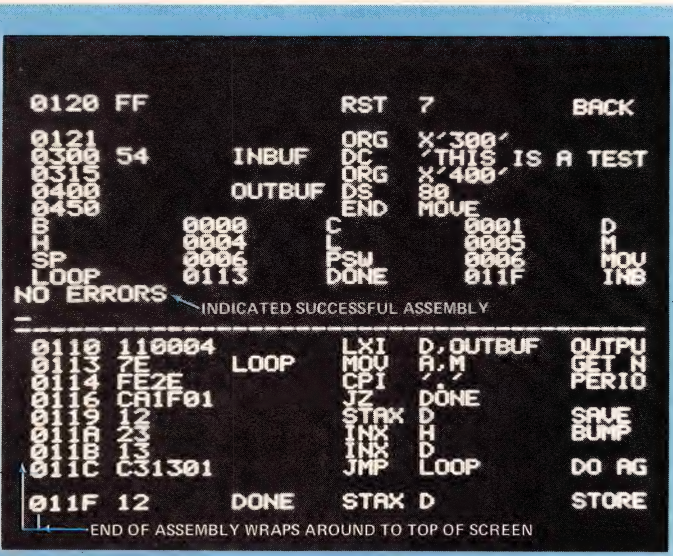
The sample application program is so short that it doesn't have any errors. But as the user starts to actually run it, he sees an improvement he'd like to make. If OUTBUF is precleared to all zeros, it will be easier for both him and the machine to distinguish the ASCII text being moved into OUTBUF from whatever values might have been there before (like erasing a blackboard before one uses it). He can easily do this by loading a zero into the accumulator and having a loop store that zero into all OUTBUF locations.

A short addition to an application program like this can often be patched in with the MONITOR/DEBUGGER's STORE command. The user "hand assembles" the code and keys it in, byte-by-byte. That, however, can get messy if one has to shift the existing code to make room for additional ones, as many of the operands in the existing code may have to be changed (like the LOOP value in our example). Therefore, the user first reloads the EDITOR and then the ASSEMBLER back into the development station. A definite advantage of having programs on cassettes rather than paper tape is that less time is required to reconvert the development station back to EDITOR and ASSEMBLER. *(Ed. Note: By the same token, having programs on floppy discs is faster still, and a decided trend exists in the more expensive versions of all these systems to offer users floppy-disc options.)*

In **Fig. 13** the EDITOR has been reloaded into the development station and the original source program read back into the system from its cassette, cassette-B. Eight new lines for preclearing OUTBUF have been added in assembly language **(Fig. 14).** (The user has typed them in ahead of the original program.) With the EDITOR it's easy to insert these new lines into the program.

The resulting assembly-language program is written onto a new, edited source-code cassette, cassette-D. For this short sample program there is room in the EDITOR's buffer to handle the revisions all at once; however, longer programs must be handled in segments.

Next, the ASSEMBLER is loaded into the development station and **Fig. 15** shows the display produced at the end of the ASSEMBLER passes. Insufficient room is available on the CRT screen to display all the lines so what's shown is the end of the program. This is the re-assembly of the original code into its new locations. Note that LOOP, which was at 106, has been shoved back to 113 by the addition. Thanks to the ASSEMBLER,



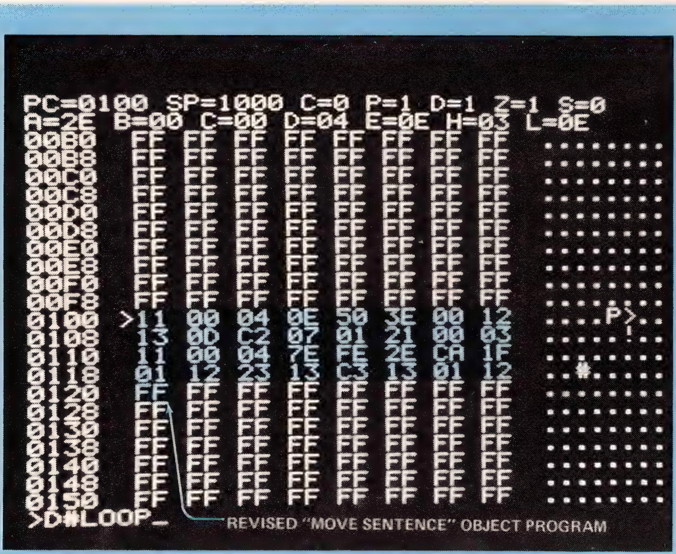
```
 0120 FF                RST  7         BACK

 0121                   ORG  X'300'
 0300 54      INBUF     DC   'THIS IS A TEST
 0315                   ORG  X'400'
 0400         OUTBUF    DS   80
 0450                   END  MOVE
 B        0000      C          0001      D
 H        0004      L          0005      M
 SP       0006      PSW        0006      MOV
 LOOP     0113      DONE       011F      INB
NO ERRORS
_
------------------------------------------------
 0110 110004            LXI  D,OUTBUF  OUTPU
 0113 7E      LOOP      MOV  A,M       GET N
 0114 FE2E              CPI  '.'       PERIO
 0116 CA1F01            JZ   DONE
 0119 12                STAX D         SAVE
 011A 23                INX  H         BUMP
 011B 13                INX  D
 011C C31301            JMP  LOOP      DO AG

 011F 12      DONE      STAX D         STORE
```

INDICATED SUCCESSFUL ASSEMBLY
END OF ASSEMBLY WRAPS AROUND TO TOP OF SCREEN

Fig. 15—The ASSEMBLER is then loaded into the development station and the new program assembled, producing this result.



```
PC=0100 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=2E  B=00 C=00 D=04 E=0E H=03 L=0E
00B0   FF  FF  FF  FF  FF  FF  FF  FF    ........
00B8   FF  FF  FF  FF  FF  FF  FF  FF    ........
00C0   FF  FF  FF  FF  FF  FF  FF  FF    ........
00C8   FF  FF  FF  FF  FF  FF  FF  FF    ........
00D0   FF  FF  FF  FF  FF  FF  FF  FF    ........
00D8   FF  FF  FF  FF  FF  FF  FF  FF    ........
00E0   FF  FF  FF  FF  FF  FF  FF  FF    ........
00E8   FF  FF  FF  FF  FF  FF  FF  FF    ........
00F0   FF  FF  FF  FF  FF  FF  FF  FF    ........
00F8   FF  FF  FF  FF  FF  FF  FF  FF    ........
0100  >11  00  04  0E  50  3E  00  12    ....P>..
0108   13  0D  C2  07  01  21  00  03    .....!..
0110   11  00  04  7E  FE  2E  CA  1F    ........
0118   01  12  23  13  C3  13  01  12    ..#.....
0120   FF  FF  FF  FF  FF  FF  FF  FF    ........
0128   FF  FF  FF  FF  FF  FF  FF  FF    ........
0130   FF  FF  FF  FF  FF  FF  FF  FF    ........
0138   FF  FF  FF  FF  FF  FF  FF  FF    ........
0140   FF  FF  FF  FF  FF  FF  FF  FF    ........
0148   FF  FF  FF  FF  FF  FF  FF  FF    ........
0150   FF  FF  FF  FF  FF  FF  FF  FF    ........
>D#LOOP_
```

Fig. 16—Here is what the application program looks like on the MONITOR/DEBUGGER display after the new instructions to clear OUTBUF are inserted.

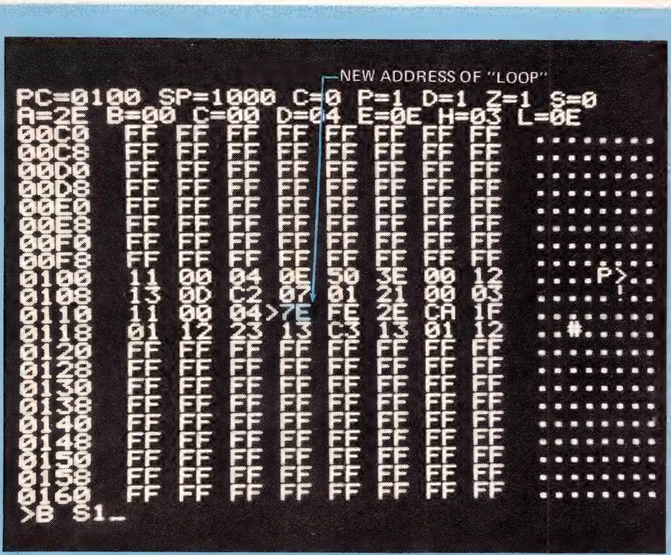
the user has not had to bother with the mechanics of this relocation.

Debugging the improved program

As the results of the ASSEMBLER passes displayed in **Fig. 15** show no errors, the user can reload the MONITOR/DEBUGGER and execute the new, enlarged version of the application program. **Fig. 16** shows the new program residing in the MONITOR/DEBUGGER RAM, in object-code form, of course. A comparison with the similar display of the original code **(Fig. 4)** shows how the program has grown and how the original code has been shifted to higher addresses in memory.

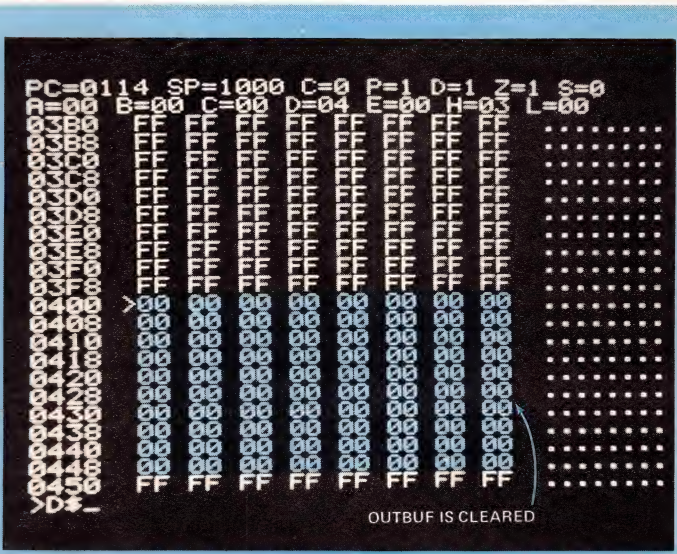
The user decides to first execute just the new code added at the beginning to see if that produces the desired clearing of OUTBUF. He quickly sets up the BREAKPOINT by setting the cursor with the D#LOOP command entered at the bottom of **Fig. 16.** In **Fig. 17,** this use of the symbolic address, LOOP, has positioned the cursor not at the old position of LOOP, 106, but at the new re-located position which is now 113.

This illustrates the great practical value of having symbolic addresses that are automatically re-located by the ASSEMBLER. Just imagine how useful this would be in the typical application where the total application program will be several thousand bytes long and you have made



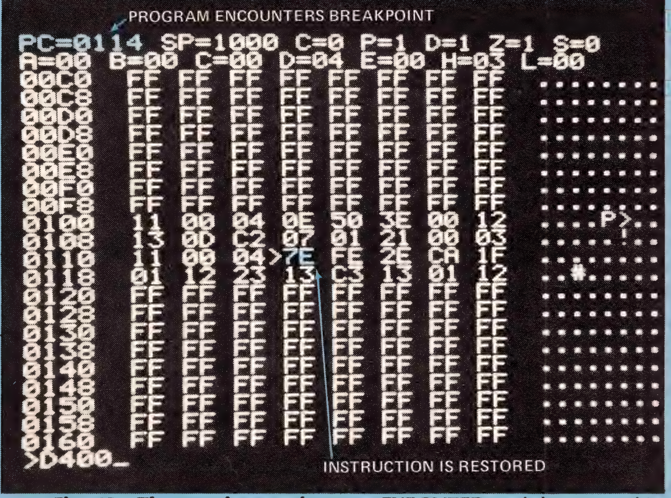
```
PC=0100 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=2E B=00 C=00 D=04 E=0E H=03 L=0E
00C0   FF FF FF FF FF FF FF FF   ........
00C8   FF FF FF FF FF FF FF FF   ........
00D0   FF FF FF FF FF FF FF FF   ........
00D8   FF FF FF FF FF FF FF FF   ........
00E0   FF FF FF FF FF FF FF FF   ........
00E8   FF FF FF FF FF FF FF FF   ........
00F0   FF FF FF FF FF FF FF FF   ........
00F8   FF FF FF FF FF FF FF FF   ........
0100   11 00 04 0E 50 3E 00 12   ....P>..
0108   13 0D C2 07 01 21 00 03   .....!..
0110   11 00 04>7E FE 2E CA 1F   ........
0118   01 12 23 13 C3 13 01 12   ..#.....
0120   FF FF FF FF FF FF FF FF   ........
0128   FF FF FF FF FF FF FF FF   ........
0130   FF FF FF FF FF FF FF FF   ........
0138   FF FF FF FF FF FF FF FF   ........
0140   FF FF FF FF FF FF FF FF   ........
0148   FF FF FF FF FF FF FF FF   ........
0150   FF FF FF FF FF FF FF FF   ........
0158   FF FF FF FF FF FF FF FF   ........
0160   FF FF FF FF FF FF FF FF   ........
>B S1_
```

Fig. 17—What happens if the user employs one of the "old" labels as an argument for a MONITOR/DEBUGGER commands? It still works, which shows the value of having symbols. They remain useful even after extensive revisions of the program. As a preliminary check on the accuracy of the new instructions, the operator here inserts a BREAKPOINT at the end of the added instructions.



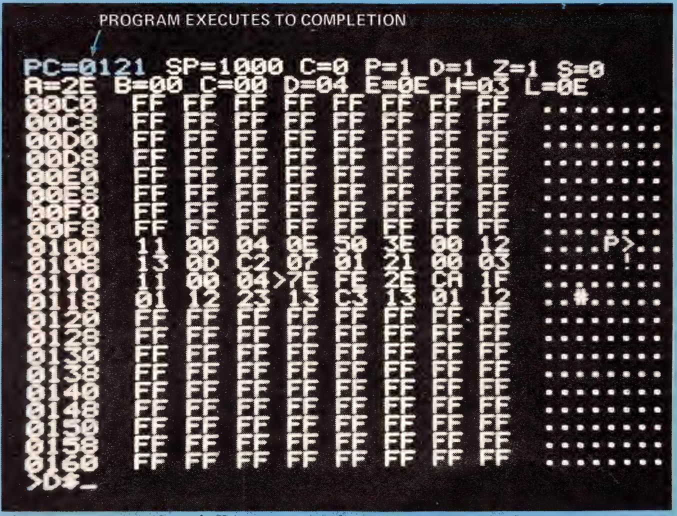
```
PC=0114 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=00 B=00 C=00 D=04 E=00 H=03 L=00
03B0   FF FF FF FF FF FF FF FF   ........
03B8   FF FF FF FF FF FF FF FF   ........
03C0   FF FF FF FF FF FF FF FF   ........
03C8   FF FF FF FF FF FF FF FF   ........
03D0   FF FF FF FF FF FF FF FF   ........
03D8   FF FF FF FF FF FF FF FF   ........
03E0   FF FF FF FF FF FF FF FF   ........
03E8   FF FF FF FF FF FF FF FF   ........
03F0   FF FF FF FF FF FF FF FF   ........
03F8   FF FF FF FF FF FF FF FF   ........
0400  >00 00 00 00 00 00 00 00   ........
0408   00 00 00 00 00 00 00 00   ........
0410   00 00 00 00 00 00 00 00   ........
0418   00 00 00 00 00 00 00 00   ........
0420   00 00 00 00 00 00 00 00   ........
0428   00 00 00 00 00 00 00 00   ........
0430   00 00 00 00 00 00 00 00   ........
0438   00 00 00 00 00 00 00 00   ........
0440   00 00 00 00 00 00 00 00   ........
0448   00 00 00 00 00 00 00 00   ........
0450   FF FF FF FF FF FF FF FF   ........
>D$_
```

Fig. 19—A check of the OUTBUF area shows that the new instructions have cleared it to zero.



```
PC=0114 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=00 B=00 C=00 D=04 E=00 H=03 L=00
00C0   FF FF FF FF FF FF FF FF   ........
00C8   FF FF FF FF FF FF FF FF   ........
00D0   FF FF FF FF FF FF FF FF   ........
00D8   FF FF FF FF FF FF FF FF   ........
00E0   FF FF FF FF FF FF FF FF   ........
00E8   FF FF FF FF FF FF FF FF   ........
00F0   FF FF FF FF FF FF FF FF   ........
00F8   FF FF FF FF FF FF FF FF   ........
0100   11 00 04 0E 50 3E 00 12   ....P>..
0108   13 0D C2 07 01 21 00 03   .....!..
0110   11 00 04>7E FE 2E CA 1F   ........
0118   01 12 23 13 C3 13 01 12   ..#.....
0120   FF FF FF FF FF FF FF FF   ........
0128   FF FF FF FF FF FF FF FF   ........
0130   FF FF FF FF FF FF FF FF   ........
0138   FF FF FF FF FF FF FF FF   ........
0140   FF FF FF FF FF FF FF FF   ........
0148   FF FF FF FF FF FF FF FF   ........
0150   FF FF FF FF FF FF FF FF   ........
0158   FF FF FF FF FF FF FF FF   ........
0160   FF FF FF FF FF FF FF FF   ........
>D400_
```

Fig. 18—The new instructions are EXECUTED and the control is returned to the MONITOR/DEBUGGER at the BREAKPOINT.



```
PC=0121 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=2E B=00 C=00 D=04 E=0E H=03 L=0E
00C0   FF FF FF FF FF FF FF FF   ........
00C8   FF FF FF FF FF FF FF FF   ........
00D0   FF FF FF FF FF FF FF FF   ........
00D8   FF FF FF FF FF FF FF FF   ........
00E0   FF FF FF FF FF FF FF FF   ........
00E8   FF FF FF FF FF FF FF FF   ........
00F0   FF FF FF FF FF FF FF FF   ........
00F8   FF FF FF FF FF FF FF FF   ........
0100   11 00 04 0E 50 3E 00 12   ....P>..
0108   13 0D C2 07 01 21 00 03   .....!..
0110   11 00 04>7E FE 2E CA 1F   ........
0118   01 12 23 13 C3 13 01 12   ..#.....
0120   FF FF FF FF FF FF FF FF   ........
0128   FF FF FF FF FF FF FF FF   ........
0130   FF FF FF FF FF FF FF FF   ........
0138   FF FF FF FF FF FF FF FF   ........
0140   FF FF FF FF FF FF FF FF   ........
0148   FF FF FF FF FF FF FF FF   ........
0150   FF FF FF FF FF FF FF FF   ........
0158   FF FF FF FF FF FF FF FF   ........
0160   FF FF FF FF FF FF FF FF   ........
>D$_
```

Fig. 20—Now the full program is EXECUTED and runs to completion.

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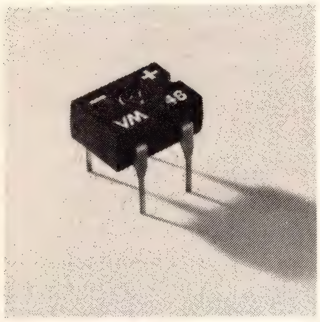

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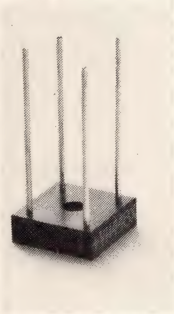

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- Fast recovery series

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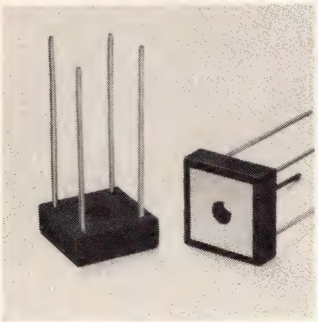
- 2A has 50A surge (I_{FSM})
- 6A has 100A surge (I_{FSM})
- Controlled avalanche series (250V to 850V min V_{BR})
- 2A Fast Recovery Series



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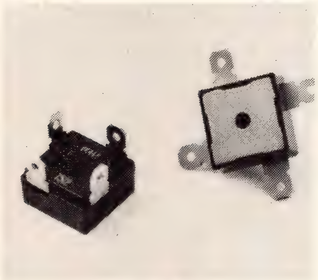

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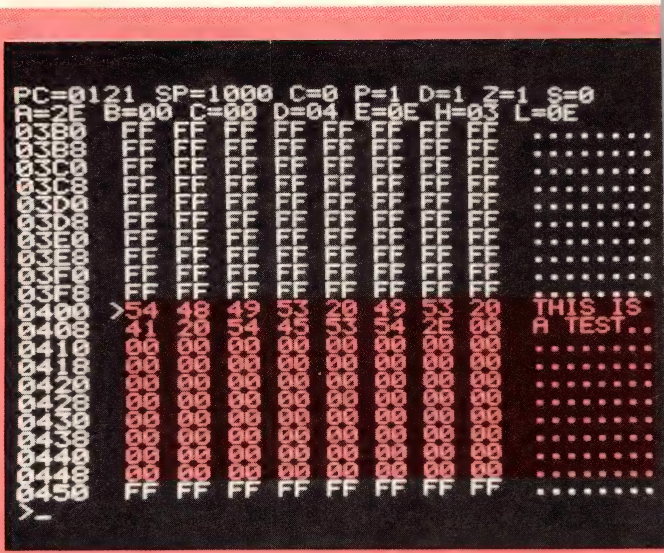

```
PC=0121 SP=1000 C=0 P=1 D=1 Z=1 S=0
A=2E B=00 C=00 D=04 E=0E H=03 L=0E
03B0   FF FF FF FF FF FF FF FF   ........
03B8   FF FF FF FF FF FF FF FF   ........
03C0   FF FF FF FF FF FF FF FF   ........
03C8   FF FF FF FF FF FF FF FF   ........
03D0   FF FF FF FF FF FF FF FF   ........
03D8   FF FF FF FF FF FF FF FF   ........
03E0   FF FF FF FF FF FF FF FF   ........
03E8   FF FF FF FF FF FF FF FF   ........
03F0   FF FF FF FF FF FF FF FF   ........
03F8   FF FF FF FF FF FF FF FF   ........
0400  >54 48 49 53 20 49 53 20   THIS IS 
0408   41 20 54 45 53 54 2E 00   A TEST..
0410   00 00 00 00 00 00 00 00   ........
0418   00 00 00 00 00 00 00 00   ........
0420   00 00 00 00 00 00 00 00   ........
0428   00 00 00 00 00 00 00 00   ........
0430   00 00 00 00 00 00 00 00   ........
0438   00 00 00 00 00 00 00 00   ........
0440   00 00 00 00 00 00 00 00   ........
0448   00 00 00 00 00 00 00 00   ........
0450   FF FF FF FF FF FF FF FF   ........
>_
```

Fig. 21—A final check of OUTBUF shows that the sentence from INBUF has been deposited in the field of zeros.

up dozens of labels to refer to major subsections of your program! A further benefit of symbolic labels available during the MONITOR/DEBUG phase (which means that the label table created by the ASSEMBLER is left or re-entered into RAM for the MONITOR/DEBUGGER) is that you don't have to wait for a printer to slowly bang out a hard-copy listing at the end of each ASSEMBLER re-run, from which you manually pick off the program locations.

So the user sets the BREAKPOINT at LOOP (113, bottom of **Fig. 17**) and asks for execution starting at the beginning of the program, which remains at location 100. After execution, he asks for a display of OUTBUF **(Fig. 18),** and in **Fig. 19** he sees that the new instructions have indeed precleared OUTBUF to all zeros.

Now the user can rapidly finish his debugging session. He uses the "$" argument to first shift back to the **Fig. 18** display where the cursor points to the BREAKPOINT. He clears the BREAKPOINT and asks for the remainder of the program to be executed. In **Fig. 20** he sees that the new program has been executed as desired because PC now points at 121, or one beyond the final "built-in" BREAKPOINT. He again uses "$" to get back to a final display of OUTBUF. Finally, in **Fig. 21** the user notes that the sentence from INBUF has been correctly written in OUTBUF's field of zeros.

The sample program is now complete from the software standpoint. All that remains is checking whether it will execute on the actual hardware configuration of the end application; but that will be the subject for future articles. □

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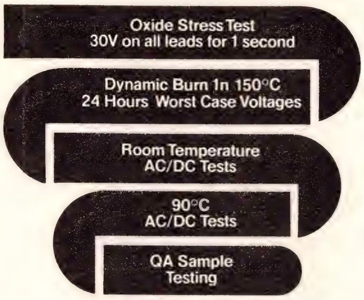

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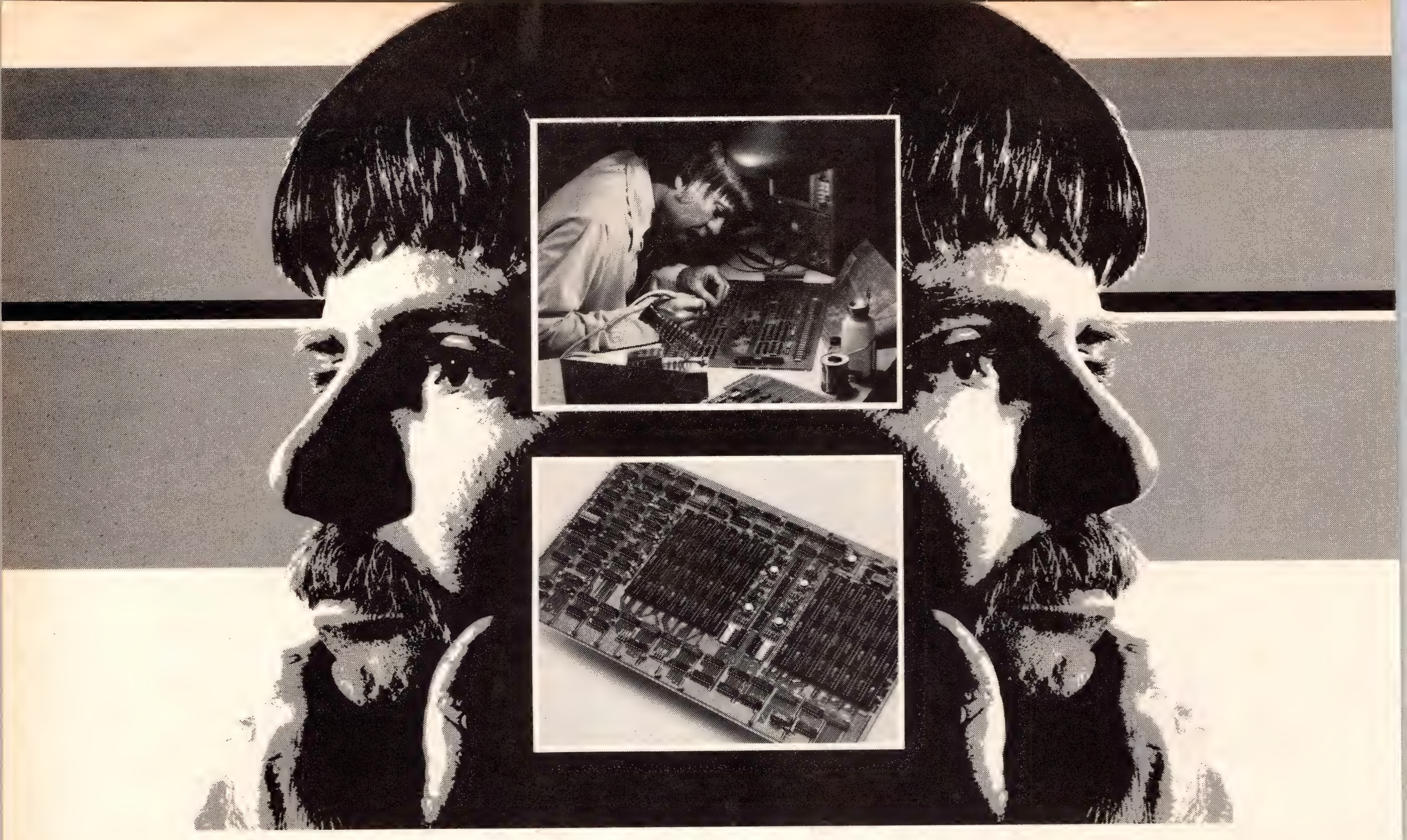

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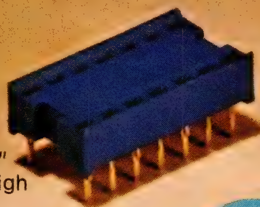

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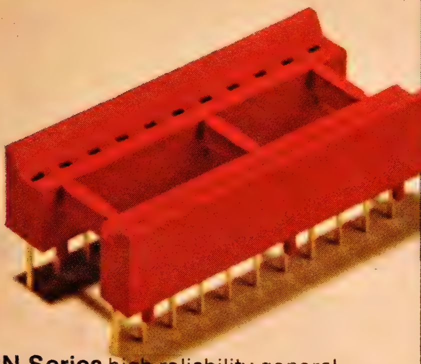

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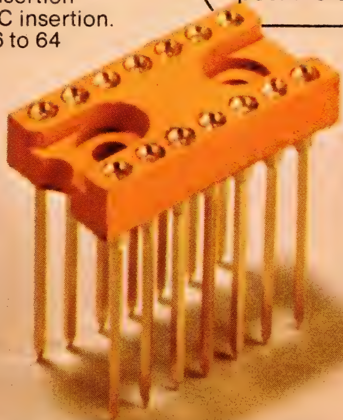

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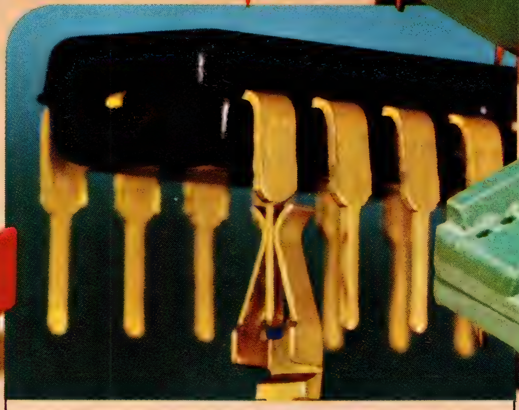

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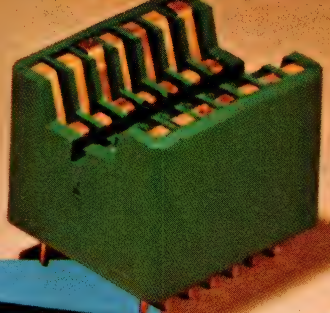

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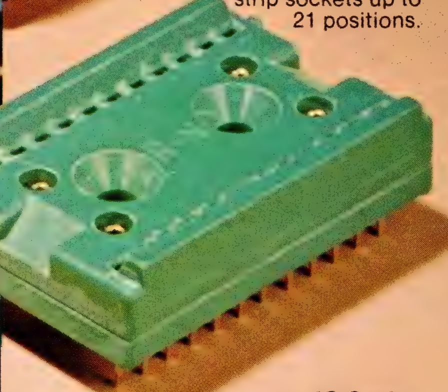

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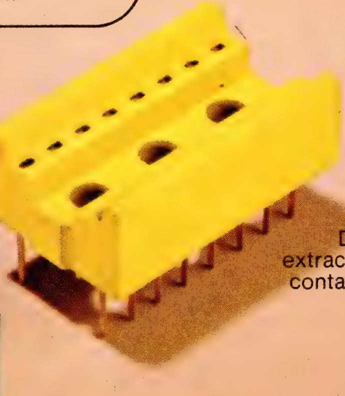

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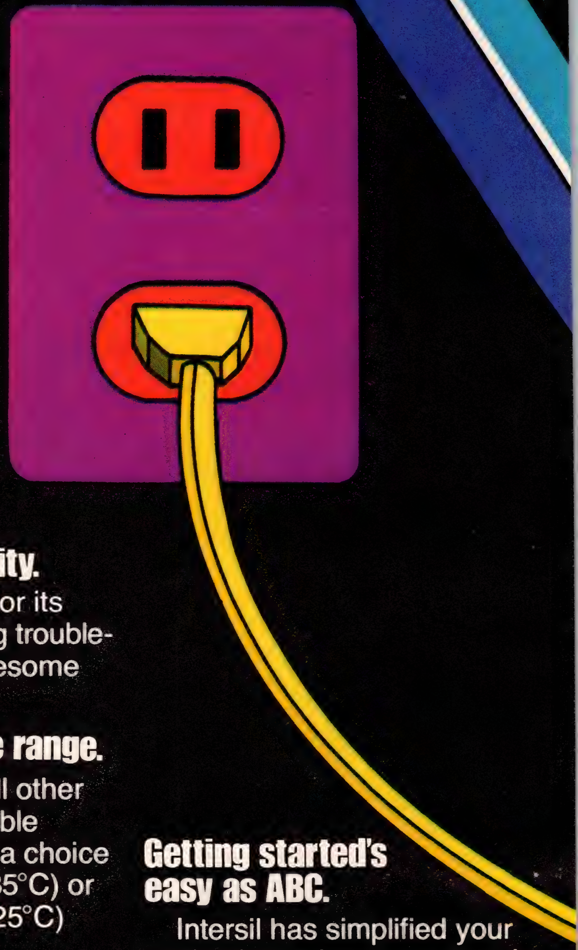
Good reasons to go CMOS/LSI with your microprocessor design.



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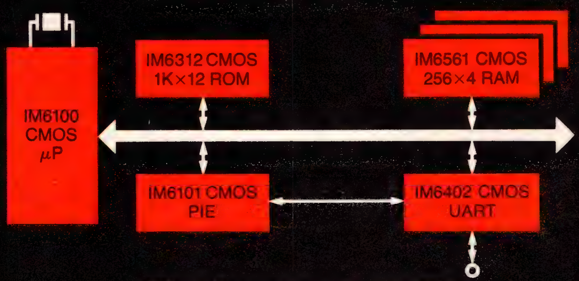

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By their very nature, CMOS circuits operate from uncomplicated, inexpensive supplies; all devices in the 6100 CMOS family use only one unregulated +4 to +11 volt supply. At 4MHz and 5V, the IM6100 dissipates only 10mW, with similar power levels for all the other members of the CMOS family. Because there's little heat, cooling problems disappear.

INTERSIL CMOS/LSI

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CMOS is famous for its noise immunity, allowing trouble-free operation in troublesome environments.

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The IM6100 and all other members of its compatible CMOS family offer you a choice of industrial (−40 to +85°C) or full military (−55 to +125°C) temperature ranges.

Inexpensive crystal clock.

Timing for the IM6100 system operation is supplied by an on-chip clock, driven by an external crystal. No clock generators or level translators needed.

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The entire IM6100 CMOS family operates well with other technologies such as NMOS, PMOS and TTL. These Intersil devices interface directly with industry-standard RAMs, P/ROMs and LSI peripheral interfaces such as UARTs, FIFOs, keyboard encoders, analog converters, modems, etc.

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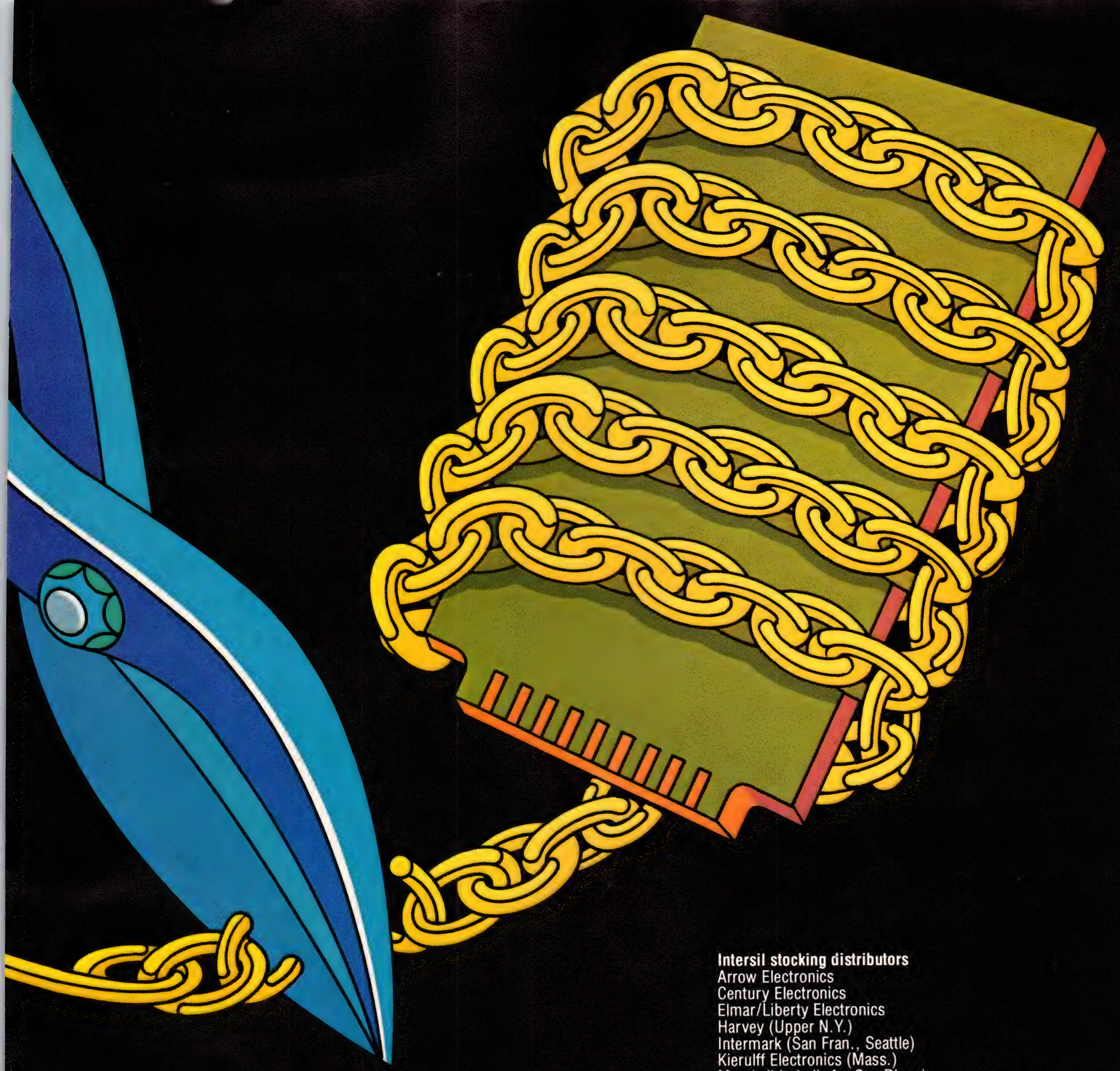

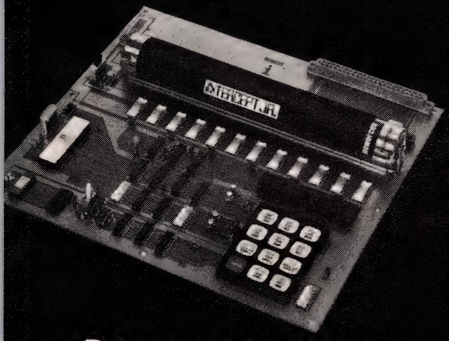

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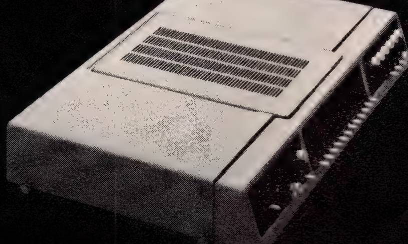

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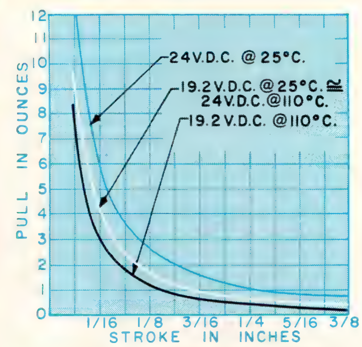
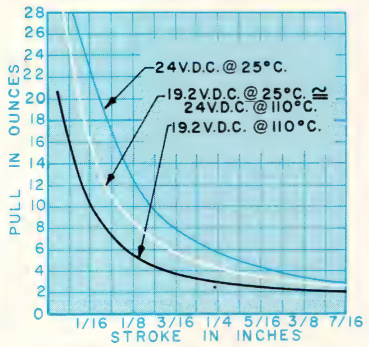


T-4 (⅞" long) Intermittent duty



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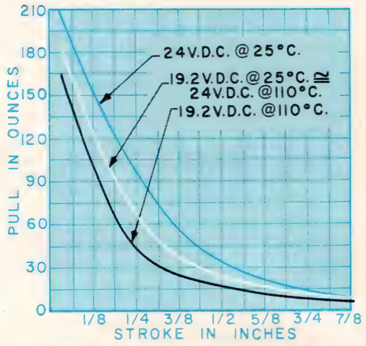

T-12 (1⅝" long) Intermittent Duty

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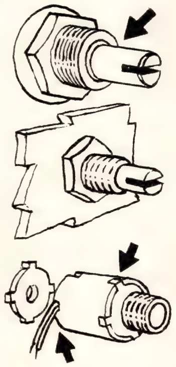
Easy to design-in. Easy to install. By design. Guardian Tubulars work in any position. Close tolerance between plunger and bobbin means no possibility of double seating. So they work in your product just the way *you* want them to work.



Mount them directly into panel by inserting threaded bushing thru installation hole and tightening nut on lock washer. Or, mount with standard bracket.

Either way, Guardian Tubulars install without damage to the solenoid. Look how the notched tube-steel shell mates with notched end plate. Result? A stronger assembly that takes more torque when installing...with no chance of damage. The leads emerge thru a notch in the steel shell, so they *will* not, *can* not be sheared by rotation during installation.

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Solving the energy crisis begins with you—the design engineer

Design standards of the past, when energy was plentiful, are now obsolete. Thus you must apply new technology to those old solutions.

Harvey Morgan, MS Laboratories

Engineers our work is cut out for us! We are the ones who have to solve the problem commonly known as the "energy crisis."

Since we design the equipment that consumes most of the energy generated, we have a responsibility to make our designs as energy-conscious as we technically and economically can. But such conservation of energy is more complex than just reducing equipment energy consumption.

For example, let's look at the components used in the equipment we design. Each component is manufactured with an expenditure of materials, labor and energy. The costs of these materials generally relate to the cost in energy to produce them, regardless of source. If a material is expensive, the cost usually results from the amount of energy used in production. Yet high price per unit quantity is not necessarily a reason not to use a particular material. Instead the major factor in the decision should be long-term cost vs. other possible materials. If a material has a short life in service, its long-term cost may well be higher than a more expensive, yet longer life, material. Replacement cost, including service charges, and continued availability at reasonable cost should be considered.

Apply new knowledge to old solutions

The standards of the past, then, when energy was plentiful, no longer hold true. Devices used to produce light are prime examples. The energy content of the radiated visible light from an incandescent filament is a small fraction of 1% of the energy required to heat that filament. Fluorescent lamps are better but still have 1% efficiency. An arc light, even though it has an efficiency of about 10%, has substantial drawbacks.

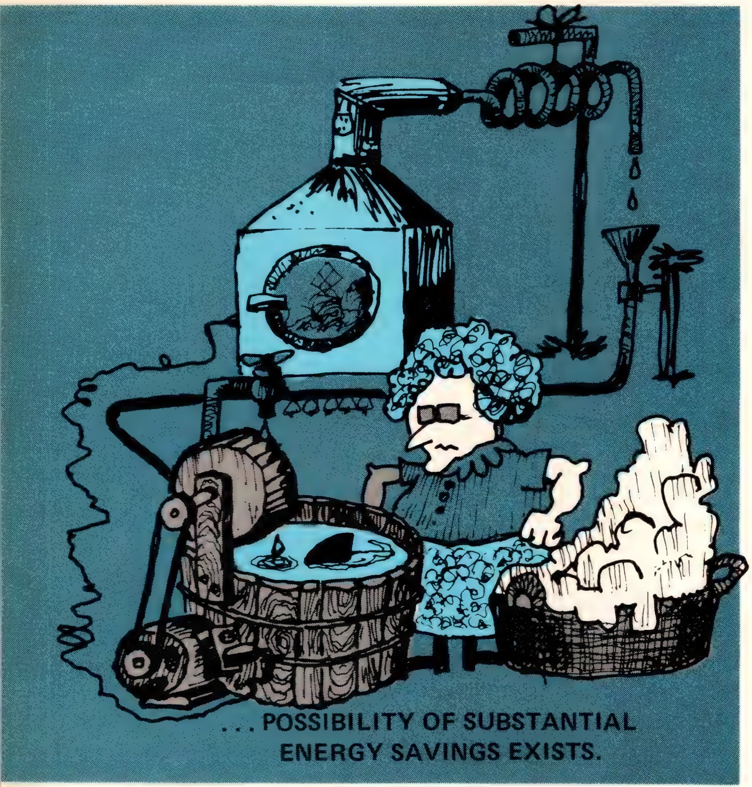
LED's provide a direct approach to light generation, offering a new solution to this old problem. The applied potential is required to cause the phenomenon of light emission. Efficiency of LED's appears to be greater than even fluorescents. Will an array of multicolor LED's constitute the white light sources of the future? What about electroluminescence?

Another example of energy inefficiency is found in hi-fi speakers—the amplifiers that drive the speakers have a *maximum* efficiency of 50%. Few though, if any, attain that value. A possible solution to this problem, then, would be switching-type amps, which can be much more efficient. Switching-type power supplies are another means of saving energy.

Other conspicuous users of energy should be closely examined for function. Consider the

Specific energy-saving design measures

- Use MOS instead of TTL when practical
- Use logic according to speed requirements
- Use only as much bandwidth as required
- Provide only essential functions
- Design equipment to switch itself off when not used
- Provide safeguards against wrong battery polarity and voltage
- Design equipment for ambient operation rather than using heaters for temperature stabilization
- Use sandwich foamed material for stiffness rather than solids
- Design for the useful life of the equipment. When will it be replaced due to obsolescence?
- Use switching mode rather than linear for high-level operation
- Minimize stages, logic, materials, costs, and energy consumption
- Keep it simple



... POSSIBILITY OF SUBSTANTIAL ENERGY SAVINGS EXISTS.

clothes dryer: Its primary function is to remove a very large part of the moisture present in clothes after washing. The present approach uses heat to cause evaporation of the water at an energy cost on the order of 2000 Btu's per pound of water. But if the water can be removed without evaporation, the energy cost will be less. Alternately, if the evaporated water can be condensed and the heat of evaporation recycled, the possibility of substantial energy savings exists.

Devices built in small quantities, even if not very energy efficient, do not greatly affect the energy problem. Small improvements in large-quantity consumer products can be very significant, though. In other words, cost of operation to the individual consumer is not the sole criterion. If a million devices are to be built, a 1% improvement is significant. Responsibility is to the nation as well as to the consumer and manufacturing company.

Management has a responsibility too

Besides the aforementioned direct responsibilities that we have, there are some indirect ones that are the responsibilities of our companies. Changes in company policy could contribute significantly in the search for a solution to the energy crisis.

Value engineering, which is not practiced in most companies, is one policy that could easily be implemented. We, as designers, need only consider the following fundamental questions *before* we start to design.

- What are the basic functions our design must accomplish?
- How essential are the functions?
- How can we design those functions to perform at the least long-term cost?
- What life and reliability are required?
- What are the modes and penalties for failure?

Whatever we design will fail some day. If the failure is a nuisance, the value of reliability is much less than if the safety of lives is involved. These value judgements directly affect cost and total equipment energy consumption.

Patents are another area sorely in need of change. Many companies require patent agreements which take title to all inventions by their employees whether they have an interest in putting them on the market or not. Submitted ideas get buried in company files and don't see the light of day until someone else invents them, or their time passes. Immediate release of inventions not within the product interest of the company might do much to relieve the energy crisis.

Electrical codes often aren't adaptable to new developments. LED's, mentioned earlier, are a case in point. Their voltage requirements are far less than 115V house supply, and they require direct current. Voltage transformation and rectification for individual devices are much less expensive than previously. In the event of LED lights, the most cost-effective method possibly would be to transform and rectify the ac to 24V dc, distribute that, and use small local dc-dc converters to power the lights. This is an example

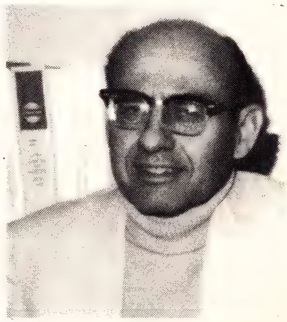
... IDEAS GET BURRIED IN COMPANY FILES ...

ENGINEERS—OUR WORK IS CUT OUT FOR US!

of new approaches to old problems, but political action may be needed to implement such changes. Laws and codes "cast in concrete" may need to become more flexible if the energy crisis is to be alleviated.

Engineers—our work is cut out for us! ☐

Author's biography



Harvey Morgan, chief engineer at MS Labs in Dallas, received both his B.S. and M.S. in physics from the Univ. of Idaho. His present duties are the design and development of bandwidth compression/expansion equipment. Harvey holds two patents, is a member of IEEE and has the unusual hobbies of archeology and lapidary, which take him to equally unusual places.

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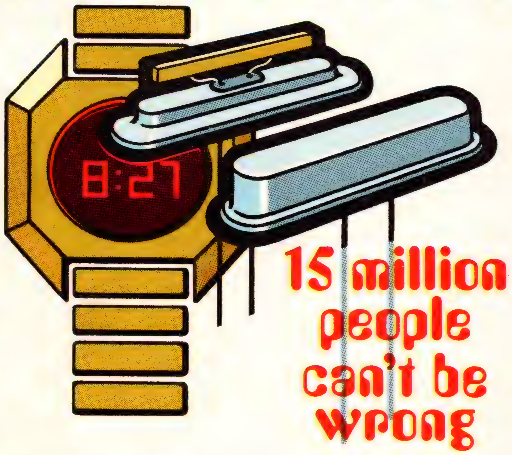
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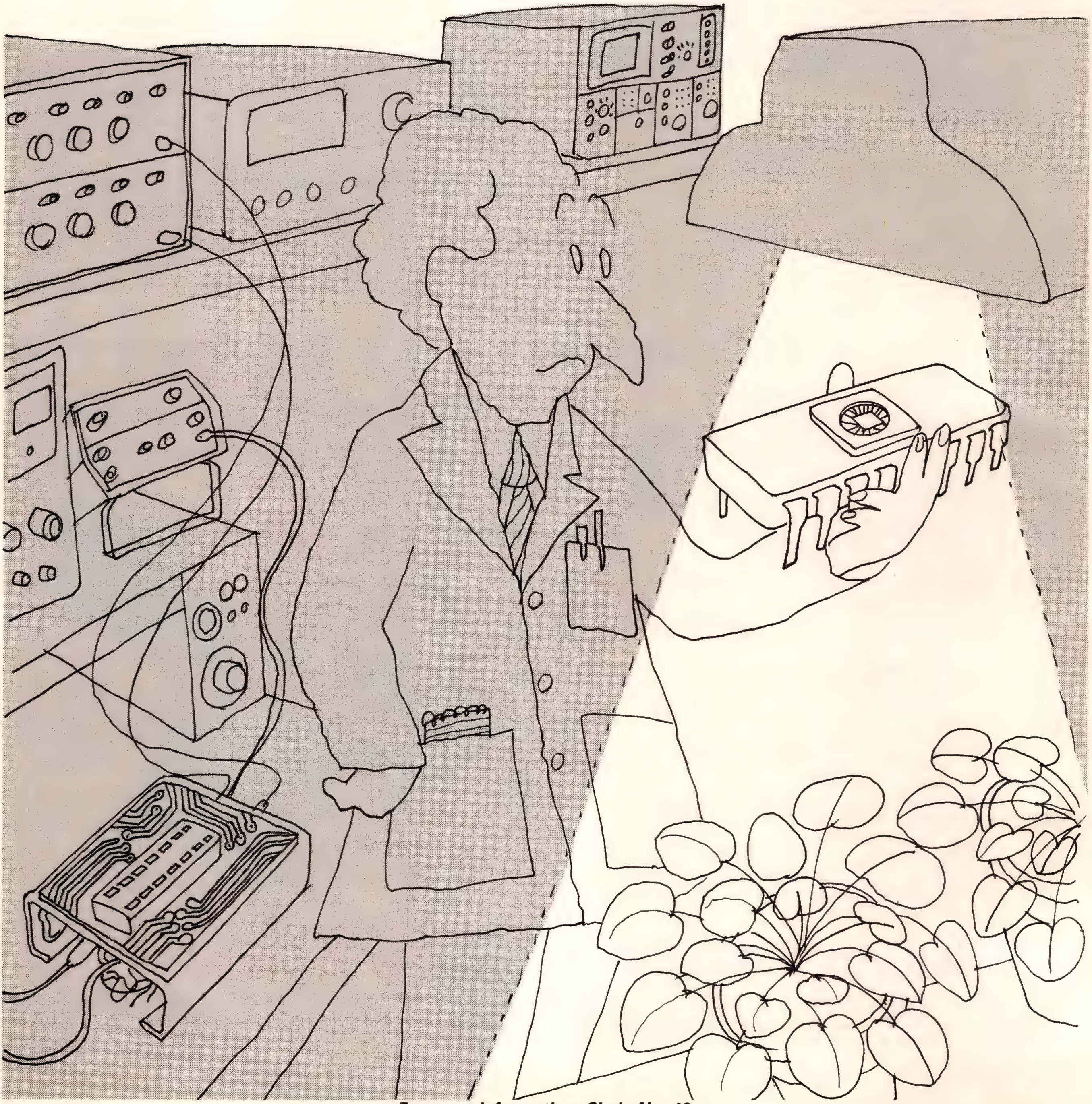

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Try the sampling comparator in your next A/D interface design

Designed to solve problems associated with comparison uncertainties, this new device can reduce the complexity of high-speed conversions.

Stan Dendinger, Hughes Aircraft Co.

Analog voltage comparators were the traditional interface between the analog and digital worlds long before the introduction of the sampling comparator. However, from an overall system-performance viewpoint, the older conventional comparator designs left much to be desired. In spite of impressive gains made in decreasing comparator-response time, **Table 1,** their inadequacies and ripple-through effect on following circuitry created a significant barrier to higher system performance.

The main problems to be overcome were: device oscillation, data storage and output-data skew. Classical solutions to these problems were RC filtering at the comparator inputs, hysteresis or positive feedback, and equalization of logic inversions through the encoding tree. Unfortunately, each of these solutions exacts a performance penalty. Filtering slows system-response time, hysteresis leads to loss of resolution, and designing the logic for equal inversions requires extra gates and introduces more delay.

Sampling solves all the problems

The sampling comparator **(Fig. 1)** enables the circuit designer to obtain a combination of system speed and precision not attainable with any other device. Externally, each IC resembles a merged comparator and digital latch. When the latch terminal is at a ONE logic level, the comparator functions normally, continuously comparing the voltages on the differential inputs. But when the latch terminal is at ZERO, the comparator is locked up in its existing logic state. The distinctive difference is that the latch function is implemented in the input stage of the comparator and is designed to be extremely fast. As a result, the comparator can be unlatched for a fraction of its propagation delay and thus accurately reflect the input conditions existing at that instant. Since operating a comparator in a sampling mode breaks the feedback loop between output and input, no oscillations can occur.

TABLE 1 AVAILABLE HIGH-SPEED TTL COMPARATORS

TYPE NO.	PROPAGATION DELAY	OUTPUT SKEW	OFFSET VOLTAGE	RESOLUTION
μA710	40 nSEC	N/A	3 mV	1.4 mV
AM106	40 nSEC	N/A	3 mV	0.06 mV
μA760	25 nSEC	5 nSEC	6 mV	0.5 mV
NE527/529	25 nSEC	5 nSEC	6 mV	0.5 mV
NE521	18 nSEC	N/A	7.5 mV	0.6 mV

MAXIMUM GUARANTEED PARAMETERS AT 25°C;
100 mV INPUT STEP, 5 mV OVERDRIVE

Don't be fooled by timing similarities

Because these comparators are sampling devices, the timing relationships between the analog input voltage and the digital latch command can be superficially characterized in the same manner as an analog sample/hold circuit. However, some subtle differences exist.

Three parameters characterize the speed capabilities of a sampling circuit: acquisition time, aperture time and aperture uncertainty time. In a sampling comparator, acquisition time (called latch-enable pulse width) is the minimum time that the comparator must be unlatched to acquire and hold an input-signal change. This definition is analogous to that for a S/H circuit. When measuring the degree of input voltage change, however, performance also changes. While large input-voltage changes increase the acquisition time of sample/hold circuits, just the opposite is true for the sampling comparator.

Aperture time is the next point to consider. In a sample/hold circuit, this parameter defines time delay between generation of a hold command and sample gate turn-off. This delay depends heavily on whether the signal is periodic or random, and also on the nature of subsequent digital processing. Second-order errors occur because real analog-transmission gates do not have instantaneous turn-off characteristics.

A latching comparator totally avoids these problems. For example, proper latch operation

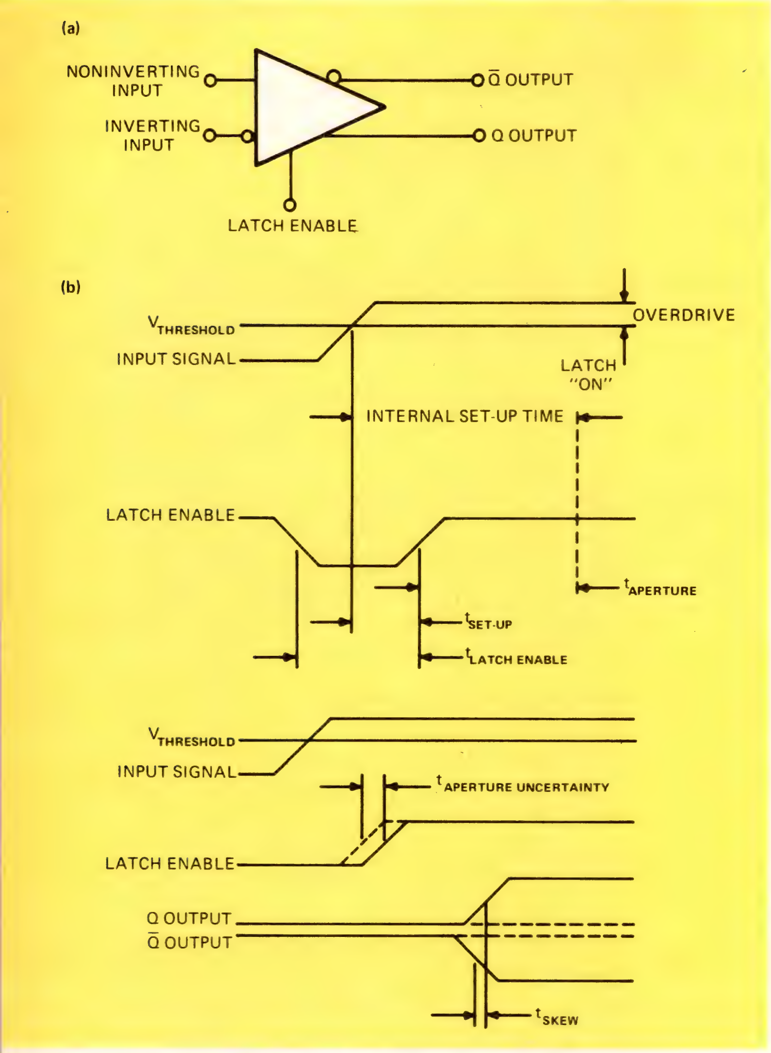


Fig. 1—Extremely fast operation is designed into the sampling comparator by implementing the latching function in the input stage. Such a design also provides a high-precision device free from oscillation problems.

requires only a slight unbalance of the input signals. Aperture time thus reduces to the delay between logic threshold crossing of the latch command and the actual turn-on of the internal latch.

For a comparator, however, aperture time is not specified directly. Rather, it determines another parameter—set-up time. This parameter specifies the minimum time an input-signal change being detected must be present to permit latching. Comparater set-up time, somewhat analogous to the data set-up time specified for digital flip-flops, is the difference between the real internal set-up time and the aperture time. Under some input-signal conditions, this set-up time can have a negative value.

Aperture uncertainty time (aperture jitter), the most critical parameter of a sampling system, is a bivarient phenomenon (specified as either p-p or rms) that always contributes error by limiting the measurement repeatability of a fixed point on a rapidly changing signal.

Because a sampling comparator quantizes dynamic errors, its aperture uncertainty time definition differs from that of a S/H circuit. Measured on a p-p basis, this parameter defines the difference in latch timing between the point at which an input signal is always detected and the point at which it is never detected. In essence, the parameter measures the time uncertainty associated with the threshold comparison.

Benefits of the latch can't be matched

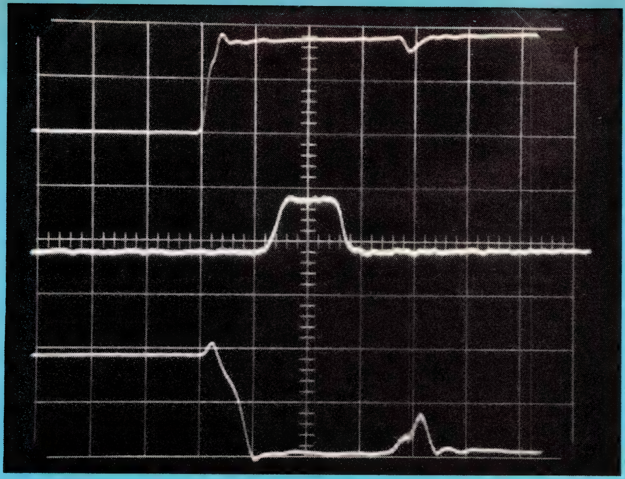
Compared to a standard strobed design, a latching comparator offers designers three major system benefits. First, its short acquisition time eliminates oscillation potential and allows detection of very brief signals.

Second, the latching comparator substantially reduces dynamic errors, because it limits threshold-comparison uncertainty time to a very small percentage of the system-clock interpulse period. Finally, operating a comparator in a sampling mode speeds its response by some 20%, since the positive feedback of the latch effectively kicks the comparator decision through the remaining output stages of the device.

While relatively easy to implement, a strobed comparator offers no special usefulness in high-speed system designs except in wired-OR applications, such as at the output of a memory device. However, such an application requires an open collector output; this configuration is incompatible with high speed.

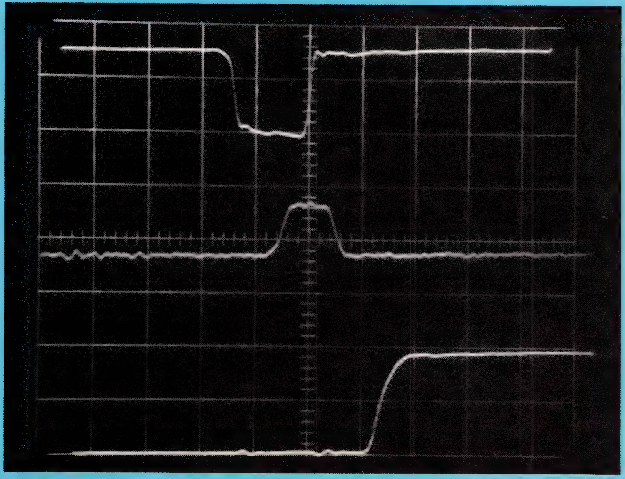
When its output gate is enabled, a strobed device may also undergo possible oscillation. Unlike a latched device, this comparator must be enabled for a time at least equal to the sum of the propagation delay through the comparator and the data set-up time of the storage flip-flop. This time can be quite long for small signals, which raises the possibility of the inputs being affected by coincident logic signals. When the output signal does appear, it still must be clocked into a digital storage device. This requires careful timing between the strobe control and the system clock.

Fig. 2 contrasts the small-signal detection capabilities of a strobed comparator with those of a latched comparator, and demonstrates the superiority of the latter. Both devices were tested under identical conditions with the inverting inputs grounded and a 5-nsec wide pulse with a 5-mV amplitude applied to the noninverting input from a 50Ω source. Pulse offset was adjusted for a baseline value of −2 mV, and the strobe and latch signals were then adjusted to the minimum values that would not degrade the comparator output signals.



STROBED COMPARATOR

HORIZONTAL: 5 nSEC/CM
VERTICAL: STROBE (TOP) 2V/CM
INPUT (MIDDLE) 5 mV/CM
OUTPUT (BOTTOM) 2 V/CM



LATCHED COMPARATOR

HORIZONTAL: 5 nSEC/CM
VERTICAL: LATCH (TOP) 2 V/CM
INPUT (MIDDLE) 5 mV/CM
OUTPUT (BOTTOM) 2 V/CM

Fig. 2—Superior high-speed performance of the latch design is evident in this comparison against a strobed comparator. In addition to its cleaner, faster response, the latch comparator requires no additional digital storage circuitry.

The strobed comparator requires output-enabling at least 7 nsec before the arrival of the input signal. In this case, the output barely exceeded the logic threshold level 13 nsec after the input signal was applied, and the probability of its being entered into a following flip-flop was very low. The latched comparator, on the other hand, exhibited a 7-nsec acquisition time and a set-up time of 3 nsec. Its output crossed the logic threshold 9 nsec after the input signal was applied, and no further digital storage was required.

Here's an example to prove the point

A 3-bit A/D converter, **Fig. 3,** illustrates the capability of the latch comparator in a typical system application. Seven AM686 comparators (from AMD) are arranged for direct parallel conversion of rapidly changing input signals with no prior sample/hold conditioning. This configuration provides a severe test of the circuit's capacity for high-speed sampling, fast response time, and minimal output-data skew. The unit consists of three subsections: an input quantizer that samples ±1V video signals and converts amplitude information to 7-line linear code; a Schottky TTL logic section for encoding to 3-bit offset binary; and a D/A converter to monitor the quantization process.

A voltage-divider string develops the threshold voltages required for the quantizing and encoding sections. The sampling mode of operation forces all the comparator outputs to change state simultaneously.

The monitoring D/A converter was designed to complement the expected speed of the quantizer. Each bit controls a 20-mA current switch, driving a node of an R-2R ladder network. Each switch then forces current into an identical 50Ω impedance. This arrangement equalizes switch response times since the same current is available at each node to charge stray capacitance.

The resistor network achieves binary weighting, and a 50Ω microstrip carries the resulting 0 to +1.75V output to an SMA coax connector. The D/A incorporates no digital storage, accepts the 3-bit input word directly and converts to analog within 1/2 LSB in 4 nsec.

To maintain 3-bit accuracy, the maximum quantization error should be held to ±1/2 LSB or ±125 mV. In other words, a signal level 125 mV greater than a reference threshold should always generate a high state at the comparator output. For this value of overdrive, propagation times indicate an approximately 6.0-nsec wait for the output signal, and as a general rule of thumb, approximately 80% of that time for the latch-enable control. Two Schottky gate delays of 3 nsec each add 6 nsec more, and the 4-nsec settling time of the output D/A brings the total processing time to 16 nsec, corresponding to a maximum data rate of 62.5 MHz.

The next step is to check threshold error due to aperture uncertainty time. In order to meet the Nyquist sampling criterion, the maximum input frequency to be digitized must not exceed one-half the sampling frequency or 31.25 MHz. Maximum slew rate occurs at the zero crossover point, and equals $V_{peak} \times 2\pi f$ or nearly 200 V/μsec. Aperture uncertainty is 140 psec rms or ±200 psec peak. Therefore, the maximum aperture uncertainty error equals 2×10^8 V/sec $\times \pm 2 \times 10^{-10}$ sec or ±40 mV, which is well within the allowable error budget.

Performance actually obtained (**Fig. 4**) indicates that the calculations were on the conservative side: The horizontal scale is 50 nsec/cm; the top

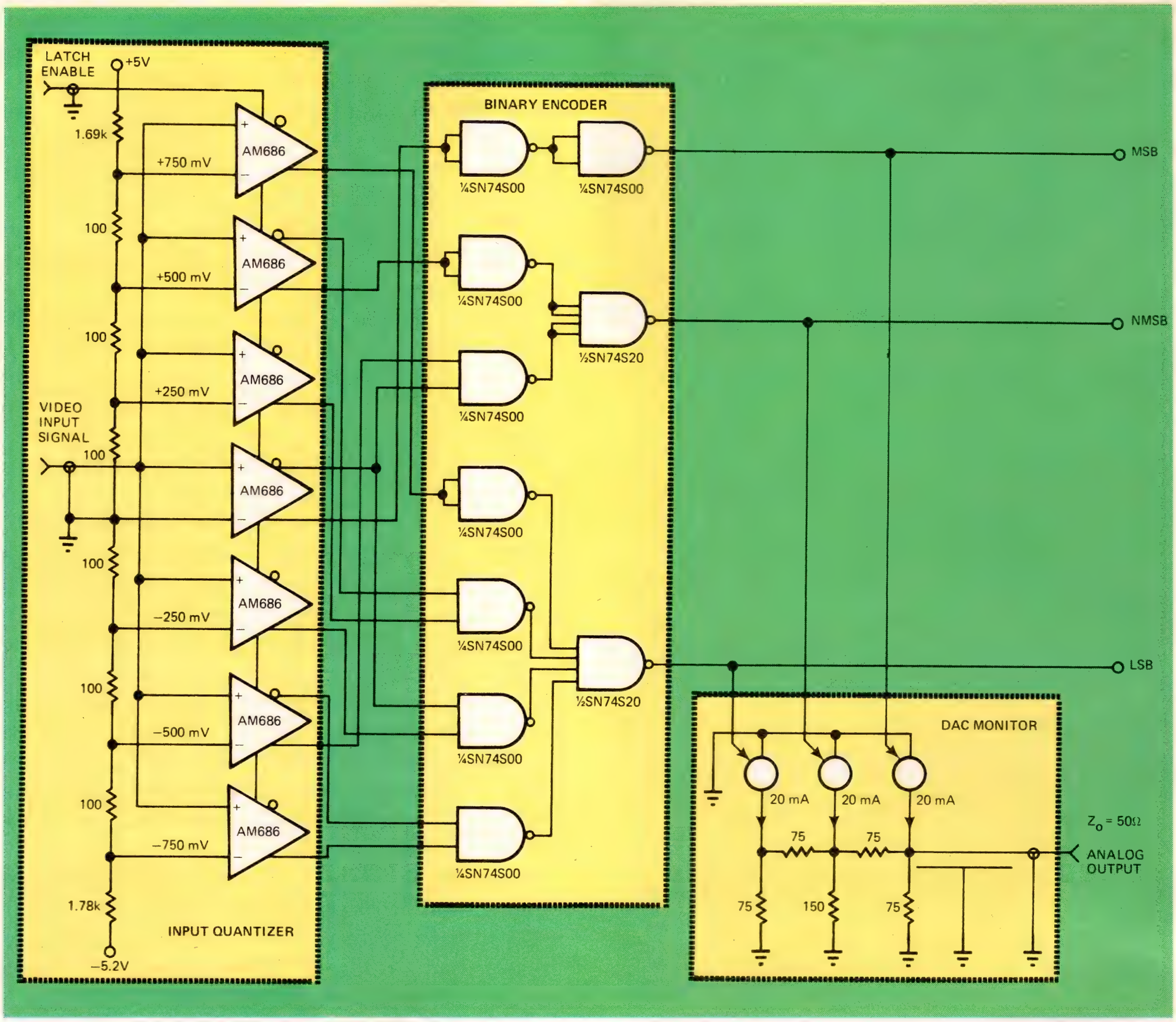


Fig. 3—A total calculated-conversion time of only 16 nsec, even with no input-signal preconditioning, testifies to the latching comparator's speed. Built around the AM686 from Advanced Micro Devices, this circuit incorporates a D/A converter to monitor the quantizing process.

waveform, the latch-enable signal switching at 80 MHz. The middle waveform is a 4.5-MHz video signal with a p-p amplitude of 1.6V. Output of the D/A showing the reconstruction of the input sine wave based on the 3-bit digital code from the comparators is shown in the bottom waveform. The unit samples the input signal, encodes to binary, and converts to analog again in less than 12 nsec. Even at this extreme conversion speed, output glitching is practically nonexistent due to the very small data skew on the comparator outputs. As expected, the worst case occurs at the zero crossover where the binary code changes from 100 to 011.

Applications areas are unlimited

This basic 3-bit circuit can extend to higher resolution converters in a number of ways. For extremely high-performance applications, the low input-offset voltages and complementary outputs allow parallel conversion of 4, 5, or 6 bits. Primary limitations, however, are layout difficulties and economics. Required resolutions of 7 bits or more would require a subranging technique.

The sampling capability of this device allows a further refinement in the converter organization. If aperture uncertainty error permits, the first quantization can be put in parallel with the analog sample/hold. This substantially reduces delay due to S/H settling time. The error in the first coarse approximation, if limited in value, can then be corrected by redundancy bits in the subranging quantizers.

At present, several comparators exist with latches available for interfacing with the most popular fast logic families. Useful not only in applications where high-speed comparator/flip-flop combinations give unsatisfactory perform-

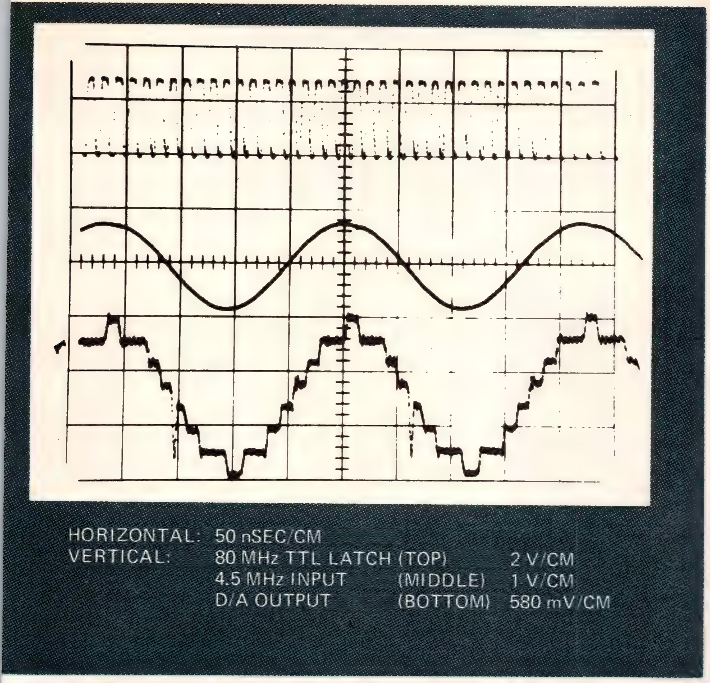
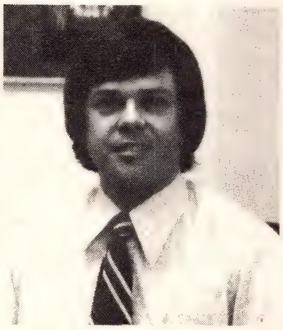


Fig. 4—Performance better than expected is shown in these A/D converter performance waveforms. Even with a total conversion time of only 12 nsec, the output is remarkably free of glitches.

ance, these comparators also allow development of inexpensive circuitry for functions once very difficult and costly to implement. Candidate areas are higher speed A/D converters, sensitive synchronous RF detectors for phrase-locked loops, optical isolators and line receivers, and ultra-fast magnetic and semiconductor memory systems, as well as a host of instrumentation and video-processing applications. □

Author's biography



Stan Dendinger is a Technical Staff Member at the Ground Systems Div. of Hughes Aircraft Co. in Fullerton, CA. With the company 10 years, Stan is presently involved in wideband analog and digital circuit design for radar-signal processing. A graduate of the Univ. of California at Berkeley (BSEE), he counts hiking, photography, chorale singing and the design and construction of stained-glass lampshades among his hobbies.

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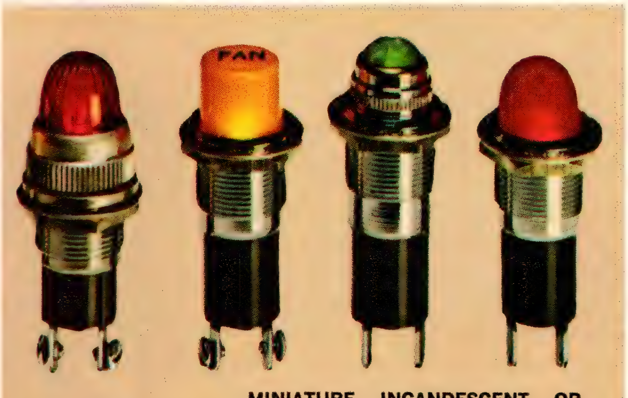

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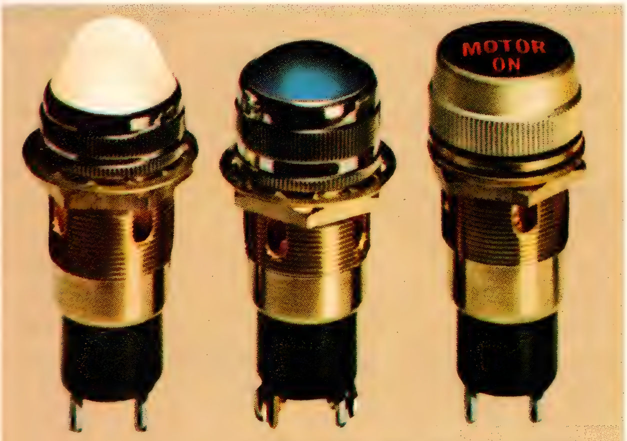

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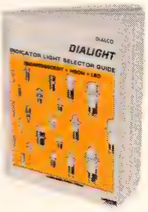

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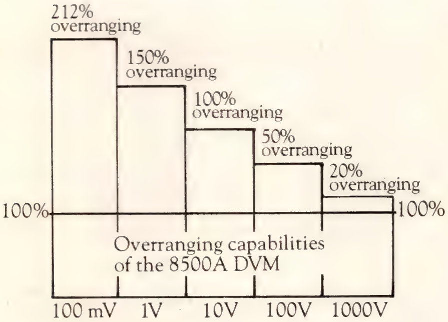
The Fluke 8500A.

It's a measurement system—not a dedicated instrument, but a bus-oriented, microprocessor-controlled measurement device. Modules which convert parameters, such as ac voltage, resistance or current, are simply plugged into any available slot in the bus structure. The microprocessor then talks to the module and displays the new value in the desired parameter.

That's the heart of the 8500A—unlimited measurement architecture. At any time, different measurement, control or servicing modules can be plugged in the bus.

And the 8500A is a different measuring device.

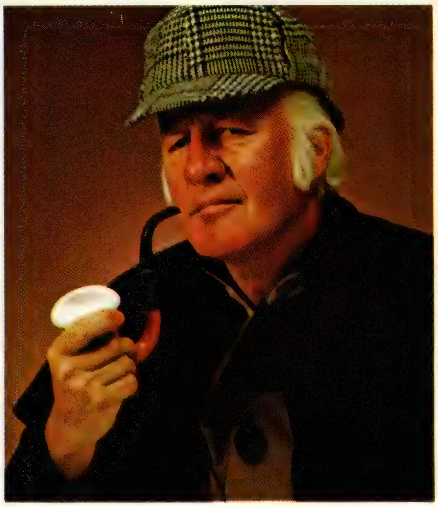
All for a basic system price of $2,695.*



Most other DVM's offer only 20%-60% overranging.

The 8500A is a high-speed 5½-digit DVM capable of 500 readings per second at full resolution and accuracy. Fluke's patented Recirculating Remainder (R^2) A/D Conversion technique is used for high, long-term accuracy and linearity. There's a calibration memory that allows for automatic correction of calibration error. And it's the only systems DVM that measures ac and dc current.

DC voltage measurement and dc ratio are standard features. DC voltages are measured over five ranges, with resolution between 1 μV and 10 mV and a basic accuracy of ±0.001% (10 ppm) for 24 hours, 20°C ±1°C. Starting with the lowest range, a maximum display of 312.5 mV is possible with a resolution of 1 μV. Displays on the lower ranges are in volts, followed by an exponent display of −3.



"It's not difficult to understand why it's called the finest. After all, it is a Fluke DVM, isn't it?"

Two types of ac measurement options are available for the 8500A. While only one can be installed in the instrument at a time, removing one option and installing the other requires a minimum of time and/or operator training. At power up or after reset, the front panel displays whether the averaging converter, true rms converter or neither is installed in the instrument.

The Averaging Converter (Option -01) measures up to 1000V ac on four ranges with a bandwidth from 30 Hz to 100 kHz and accuracies up to ±0.05% + 5 digits. The True RMS Converter (Option -09) measures up to 1000V ac on four ranges with a bandwidth from 10 Hz to 300 kHz and accuracies up to ±0.1% + 15 digits.

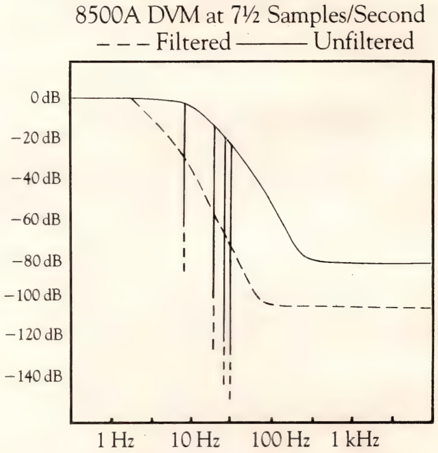
Resistance measurements can be made on eight ranges from 10Ω full scale to 100 MΩ full scale with the Ohms Converter (Option -02). Basic accuracy from 100Ω to 1 MΩ is ±0.003% + 1 digit, with resolutions up to 100 μΩ obtainable.

Both ac and dc current can be measured with the Current Module (Option -03) provided one of the ac options is installed in addition to the basic dc. Current measurements to 1A can be made with sensitivity to 1 nA. Accuracies to ±0.03% + 10 digits, for dc readings and to ±0.06% + 8 digits for ac readings. Bandwidth of the 100 μA through Amp ranges is 30 Hz to 10 kHz. For the 1A range only, the bandwidth is 30 Hz to 3 kHz.

Guaranteed accuracies for the 8500A measurement options are based on 90 days, 18°C to 23°C.

Three Remote Interface options are available with the system. Only one of the three may be installed at a time; however, one can be easily exchanged for another when the top cover is removed. This allows the instrument to be used with more than one interface system, requiring only that additional modules for the desired interfaces be obtained.

The IEEE Standard 488-1975 Bus Module (Option -05) provides an eight-bit (one byte) parallel interface. The Bit Serial Asychronous Interface Module (Option -06) interfaces the 8500A to systems using either RS232B, RS232C, or Current Loop interface. Selection of type and Baud rate is made with bit switches accessible through an entry



Fantastic noise rejection without sacrificing speed.

Automatic correction for zero, offset, calibration and drift with microprocessor controlled memory storage.

Extra digit of resolution.

As an extra bonus, the range digit can be converted to a 6th measurement digit—for 6½ digits of resolution.

port on the rear panel. And the Parallel Interface Module (Option -07) provides a 16-bit duplex register interface compatible with mini-computer and microprocessor systems.

A non-volatile calibration memory module stores correction factors desired from a standard input during CAL mode operations. It can also be used to compensate for long-term drift, eliminating the need for manual adjustments or trips to the calibration laboratory. This allows the operator to remove power from the instrument or the system to suffer a power failure without loss of automatic calibration factors. The battery permanently installed on the module will keep power on the memory to retain the stored data in excess of 90 days after removal of power.

Service capability is one of the strong points in the 8500A program. Of course, extensive overload protection has been designed into the instrument. But should problems develop, most of them can be handled in the field by using the available service aids. An extender card, a bus monitor, a test module, and a static controller, together with diagnostic programs and the microprocessor control should handle 60%-80% of most troubleshooting problems.

If you've read this far, you know why the 8500A is called the world's finest DVM. Microprocessor control, modular design, complete measurement and systems interface capability and ease of service are all combined in one instrument. And the best thing about it is that it's made by Fluke. So you know you can count on quality and service throughout the world.

The 8500A. One more reason why Fluke is the leader in digital voltmeters.

IEEE-488 interface bus	Fluke
ASC11 interface	Fluke
Parallel interface (16 bit)	Fluke

Only one system DVM offers all the interfaces you need.

18 different sample rates	Fluke
5 different filter modes	Fluke
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Store and test for limits	Fluke
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BEFORE YOU GO BACK TO THE BENCH, TAKE A LOOK AT WHAT YOU SHOULD FIND THERE.

Fluke spends a lot of time paying attention at test and measurement benches across the industry.

Out of what we hear, we develop new products.

Not just DVM's. Not just counters. But also frequency synthesizers, automatic test systems, signal generators, calibrators, logic board testers, power supplies, data loggers, digital thermometers, ac and dc standards, and differential voltmeters.

A company that listens so carefully, probably has what you've been looking for.

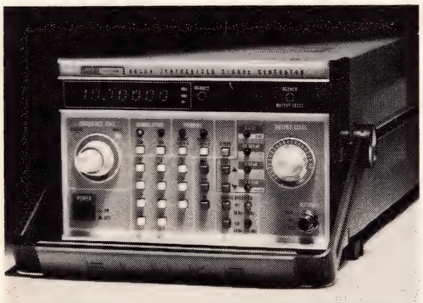
Smart, but friendly.

The Fluke 6010A Signal Generator incorporates a microprocessor for free-form entry of frequency in Hz, kHz, or MHz. The unit stores and recalls up to ten frequencies, modulation, and attenuator settings by pushing a single button—a feature unique in signal generation.

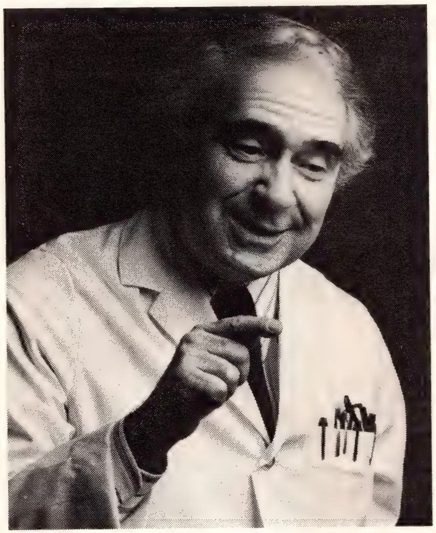
The microprocessor plays a part in several other operations, including automatic range selection and automatic justification. You can automatically justify the frequency entry on the 7-digit LED readout to give the greatest possible resolution.

But for all its sophistication, the 6010A is friendly. It's easy to use. For example, you've got continuous tuning with the Frequency Edit control—the bright digit denotes the tuned decade. The bright digit can be incremented and decremented with complete carryover and borrow capability across a 10 Hz to 11 MHz coverage.

Put this intelligent, amiable fellow to work for you for only $2495*.



6010A Signal Generator



"I'll take one of those. And one of those, too!"

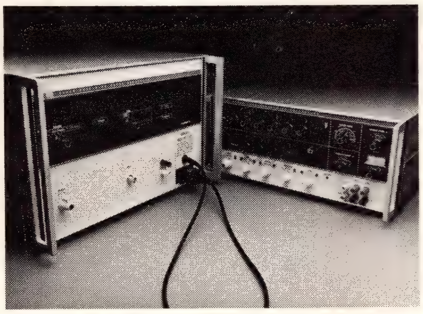
Keep up the standards on the bench.

From Fluke. A fully programmable ac cal setup with range, stability and accuracy that's hard to beat for the price.

Together, the 5200A Precision AC Calibrator and the 5205A Precision Power Amplifier can calibrate ac devices up to 1200 volts rms. Frequency range is dc to 1.2 MHz. DC output of 1600 volts is available. Maximum output current is 200 mA and will drive a 1500 pF capacitance load. Long-term stability is 200 ppm/ 6 months, midband accuracy is 0.02% overall, and response is a fast 0.5 sec.

Both instruments are short-circuit proof, fully guarded and interlocked. Phase lock availability and quadrature output are standard features.

The system interfaces easily with almost any system. Field installable serial and parallel isolated programming options are available. This unbeatable team goes to work for you for $8990*.

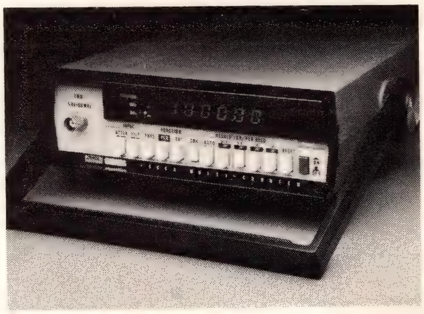


5200A AC Calibrator and 5205A Power Amplifier

Basic counting.

A new Fluke multi-function counter, the 1900A features autoranging in both frequency and period modes, with 20% hysteresis to eliminate annoying range switching. There's leading zero suppression and autoreset in all functions for easy and correct readings every time. A large 6-digit LED display with automatic range of 5 Hz to 80 MHz. Exceptional sensitivity of 25 mV (typically 15 mV). Event counting to 10^6 counts. Signal input conditioning. Frequency. Period. Totalize.

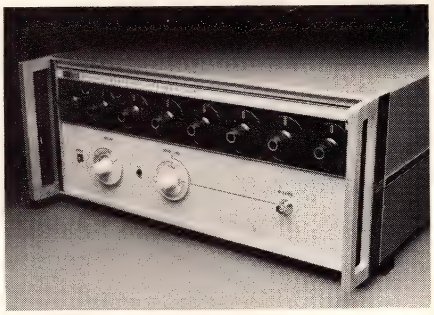
At only $375*, you could say we've stayed close to the basics.



1900A Counter

Shhhhhhhhhh.........

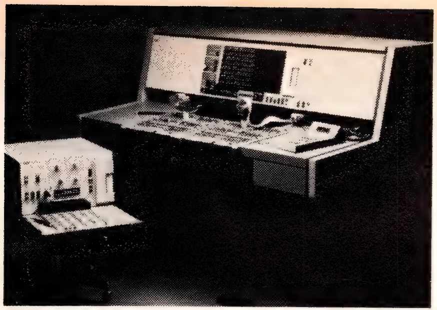
Are you doing NMR or microwave spectroscopy? Be quiet about it. Use the new Fluke 6160B Frequency Synthesizer with the best signal-to-noise ratio available and a guaranteed spurious spec of greater than −83 dB. A range of 1 to 160 MHz with 1 Hz resolution, and from 1 to 20 MHz the spur spec is −100 dB. BCD programmable frequency control. Switching speeds less than a millisecond. Modular construction for custom tailoring to your needs. And all of this quiet costs $5895*.



6160B Frequency Synthesizer

For information on 6010A—Circle #52
For information on 5200AAC—Circle #53
For information on 5205A—Circle #54
For information on 1900A—Circle #55
For information on 6160B—Circle #56

For information on 3010A—Circle #57
For information on 3020A—Circle #58
For information on 2100A—Circle #59
For information on 8800A—Circle #60
For information on 8375—Circle #61
For information on 8400A—Circle #62



3010A/3020A Logic Board Testers

Common sense logic board testing.

With the Fluke Trendar 3010A/3020A testers, you can perform logic board testing without software, programmers and lots of money.

The 3020A is a console for high-volume production applications. It comes complete with 128 pins for under $30,000*. The 3010A is a compact version for field service and low-volume production at less than half that price.

The test engineer doesn't program in the conventional sense. He simply develops a test plan which consists of selecting the appropriate stimulus algorithm for each input.

And once the test program is entered into memory, you can record it easily on a handy little magnetic credit card that looks exactly like those credit cards in your wallet. The programmed card will function interchangeably with the production Model 3020A, or the field service 3010A.

Write Don Allen and ask for "The Economics of Logic Board Testing." Everything you need to get you into logic board testing is there. Economically, for a change.

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2100A Digital Thermometer

Digital thermometers, with options.

Fluke's new series 2100A digital thermometers offer temperature range of −320°F to +3200°F with 0.1° resolution in three models.

And they've got options for maximum versatility.

Like an analog output in four offset ranges, both linearized and isolated. The linearized feature gives direct temperature readings on a strip chart recorder with no interpolation. And because it's isolated, there's no worry about ground loops.

The 2100A has a digital BCD output that monitors six thermocouple types (J, K, E, T, R and S) and two millivolt ranges: 40 and 400 mV. The unit operates from line, 12V dc or self-contained battery pack (7 hours off-line). And you can expand up to 100 points with the 2150A option.

In addition, these units are rated for a minimum 10,000-hour MTBF, have excellent noise rejection and come in tough, all-metal cases. Prices for the three basic models are $795* (2100A-03, single-point type), $995* (2100A-10, multi-point type), and $1095* (2100A-06, multi-thermocouple type).

5½-digit DVM extravaganza.

Whatever you need in a DVM—Fluke has it. We're the leader.

Let's say you need resolution to 5½ digits. Look at these three instruments.

The 8800A is a ± 0.005%, 200,000-count bench DVM with 1 μV sensitivity. It's light and small, has full guarding and autoranging, and sells for $985*. Accuracy is a guaranteed ±0.01% for 90 days over a temperature span of 18° to 28°C. Five ranges of dc volts from +200 mV to +1200V. Four ranges of ac volts from 2V to 1200V. True 4-wire resistance measurements on all ranges, 200 ohms to 20 megohms, with 3.3V maximum open post voltage. 10,000-hour MTBF. And overload protection of at least 1000V on any ac or dc range, 250 V rms or dc on any ohms range—the best in the industry. A wide range of accessories includes high-frequency probes, high-voltage probe and clamp-on ac current probe. An isolated printer output option is available.

For systems applications, Fluke offers the 8375A. Standard unit measures 5 ranges of dc volts and 4 ranges of true-rms ac volts. Basic dc accuracy is ±0.003%. Basic ac accuracy is ±0.1%. Resistance measurements are made in 7 ranges from 10 ohms to 12 megohms with 100 micro-ohms sensitivity. Fluke's patented Recirculating Remainder A-to-D conversion technique with autozero circuit provides reliable long-term accuracy and linearity. A quick check of all measurement functions is provided by the unique self-test feature. Field-installable systems options include remote control, data output and dc external reference.

The 8400A is the same basic box as the 8375A, with some different features. To the capabilities of the 8375A add ±0.002% basic dc accuracy, plug-in ac, resistance and ac or dc ratio options, switched filter for dc, ac resistance and ratio, automatic settling or time-out delays and serial or parallel data output.

Both instruments, the 8375A and 8400A, offer full autoranging, autopolarity, 20% overranging, pushbutton selection and 10,000-hour MTBF.

Both sell for $2195*.

**Domestic price only.*

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8800A, 8375A, and 8400A Digital Voltmeters

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For demonstration on 3010A—Circle #68
For demonstration on 3020A—Circle #69
For demonstration on 2100A—Circle #70
For demonstration on 8800A—Circle #71
For demonstration on 8375A—Circle #72
For demonstration on 8400—Circle #73

Microprogramming helps squeeze more from your equipment dollar

Talk to a CPU in its own language and you can "emulate" a bigger unit—or better yet, make its every operation more efficient!

Gary DesRochers, Western Digital Corp.

As microprocessors become increasingly more important tools, today's designer is often forcibly "inspired" to learn sophisticated programming techniques. However, a lack of experience in this area often leads to the substitution of more easily understood, higher level compiler-derived languages. Such languages may require less time to write the program, but one should be aware of the consequences: These languages are often inefficient tools for even a simple job! A microprogrammer, on the other hand, can make his machine do what he wants, the way he wants it done, and with less computational time (i.e., dollars!).

Microprogramming is simply the use of a program language that controls the sequence of internal machine-hardware functions. In this language, microinstructions specify control terms that cause the machine hardware to perform an elemental function such as transferring a piece of data from one register to another. The device is then completely software driven, having no predetermined sequence of operations implemented in hardware; linkages of microinstructions cause the machine to perform the desired function.

One should recognize, however, that not all machines can be microprogrammed; the machine's architecture must be designed for microprogrammable control. Depending on the particular system in question, microprogramming may be applied to any of the various software-controlled logic systems (known as processors), including μP's, mini's and mainframes.

Is BASIC really basic?

Very often a program is written in a higher-level language such as BASIC or FORTRAN. These languages use very general instructions that must be "massaged" through several levels of translation before commands are in a form the machine can act upon (**Fig. 1**). The use of such languages often results in an inefficient program in comparison to direct coding of the machine in its own elementary language.

LANGUAGE LEVEL	INSTRUCTION	COMMENTS
'BASIC' LANGUAGE STATEMENT	Y - A*B	ADD 'A' + 'B', STORES RESULT IN Y REGISTER
TYPICAL MACRO ASSEMBLY LANGUAGE	LD A, Y	LOAD MEMORY OPERAND A INTO ACCUMULATOR R1
	ADD B, Y	ADD MEMORY OPERAND B TO ACCUMULATOR R1
MICRO ASSEMBLY LANGUAGE	RIW2 PCH, PCL	READ OUT PROGRAM COUNTER ADDR
	IW RIR	INPUT MACRO INSTRUCTION TO INSTRUCTION REGISTER
	R AH, AL	READ OUT ADDRESS OF A OPERAND
	IW RTEMI	INPUT A
	R BH, BL	READ OUT ADDRESS OF B REGISTER
	IW Y	INPUT B
	AW RTEMI, Y	ADD A + B

Fig. 1—As a designer progresses in the hierarchy of computer languages from higher level ones such as BASIC to a microprogramming language, the number of programming steps as well as control and efficiency increases.

In general, then, execution of a single instruction issued by a high-level language is no faster than if the instruction were microprogrammed; indeed, execution in the higher level language would most probably take at least several times longer.

An efficiency comparison analogous to this micro/macro case occurs every day with respect to the routing of telephone calls. Phone signals must travel to a central exchange before being routed to the desired location, even if that location is the house next-door—this is the macro-approach. The micro-approach, of course, is simply to yell out an adjacent window: The information reaches its final destination without any detours or interruptions.

Likewise, a macroprogram may require that a piece of data sit in an intermediate register before reaching its desired location, while a microinstruction can transfer data directly. Such a "straight-line" approach occurs through the acquisition of microinstructions from a high-speed dedicated memory channel rather than through usage of a slower access memory channel predetermined by general-purpose macroinstructions (**Fig. 2**).

For example, an 8×16-bit binary multiply routine, when incorporated in external memory programs, typically takes 200-250 μsec in a

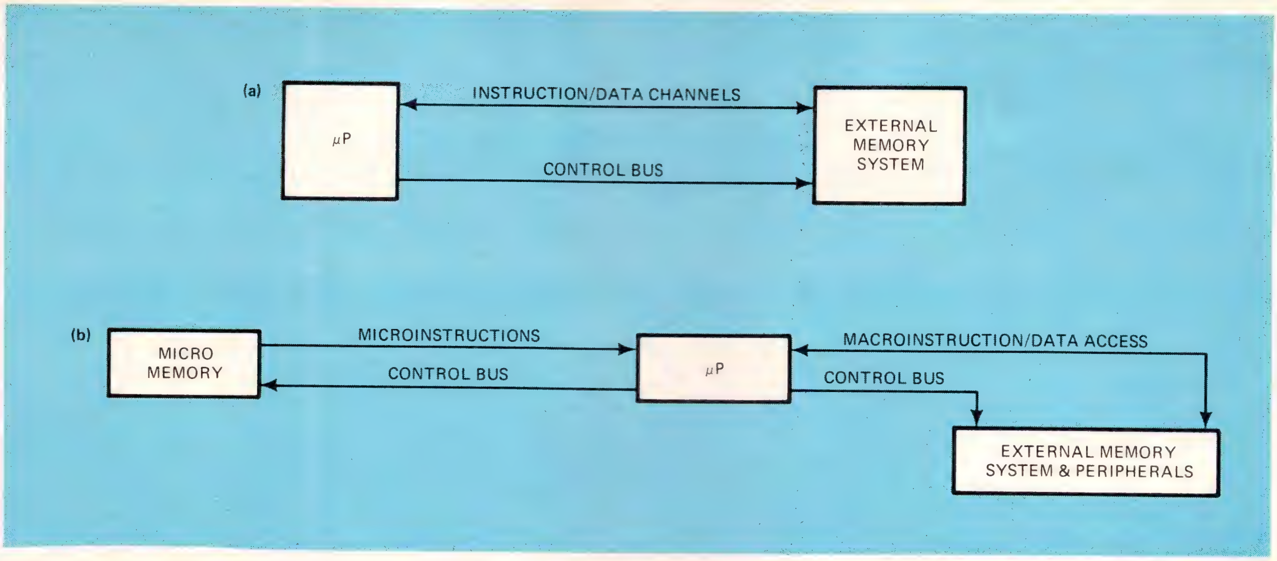

Fig. 2—Typically requiring 1.5 μsec per data instruction, a macroinstruction machine **(a)** needs much more overhead time than a macroinstruction machine's **(b)** 0.2 μsec per microinstruction access.

popular microprocessor. When incorporated as a routine in micromemory (where all microinstructions are stored), the same routine requires less than 30 μsec. In addition, since the micromemory stores these routines, the amount of external memory normally used to store subroutines and branch instructions (needed to access subroutines) is correspondingly reduced.

A copy better than the original

Besides the speed factor, microprogrammable architecture can behave in the same manner as an existing high-level processor. This mimicking of a desirable high-level structure by programming subroutines in micromemory is called "emulation." Such emulations may result in a system smaller and less expensive than the original, but this new system operates on the same, previously derived software.

Also at the emulation level, one can expand the instruction capability contained in the emulated machine's repertoire by creating subroutines and associating them with unused instruction operation (OP) codes. That design changes can be made in the field simply by replacing a micromemory element indicates how easily an instruction set can be replaced.

The ease of changing the processor for design expansions proves another major advantage of microprogramming. Since software controls all functions in the machine, the designer may add or replace programs in the micromemory to create improved machine capability instead of having to rebuild hardware. This adaptability allows one system design to meet several applications such as a communications line concentrator, floppy-disc controller/formatter, bus controller, etc.

Despite the advantages of microprogramming, there are some drawbacks. Microprogramming, in general, takes more initial programming time than does higher level programming, since the incremented steps are smaller. A customized microprogrammed machine can be somewhat more expensive than a fixed-instruction device, due to the additional software-development time required as well as possible masking charges needed when implementing nonvolatile micromemory storage (ROM).

The concept of a microprogrammable machine is not new. Conceived in the early 50's, this idea was actually realized in a number of minicomputers during the 60's. Some of the most recent efforts have occurred in the development of microprogrammable microprocessors: One example is the 3-chip MCP1600 system by Western Digital Corp. (**Fig. 3**) that is particularly well-suited for emulation applications. (Digital Equipment Corp. uses the MCP1600 in its LSI-11 system to emulate the PDP-11/40 instruction set.)

Do your PLA's speak the same language?

To emulate a given machine, a microprocessor must be able to decode a pre-determined language into controls that perform the required functions. In the MCP1600, this translation is accomplished by the Programmed Translation Array (PTA) that is comprised of a pair of programmable logic arrays. The PTA provides automatic linkage and calling of the necessary microprogram ROM (MICROM) subroutines as a function of the macroinstruction inputs.

As an emulator, its prime requirements are: (1) fast speed to rapidly execute the sequential

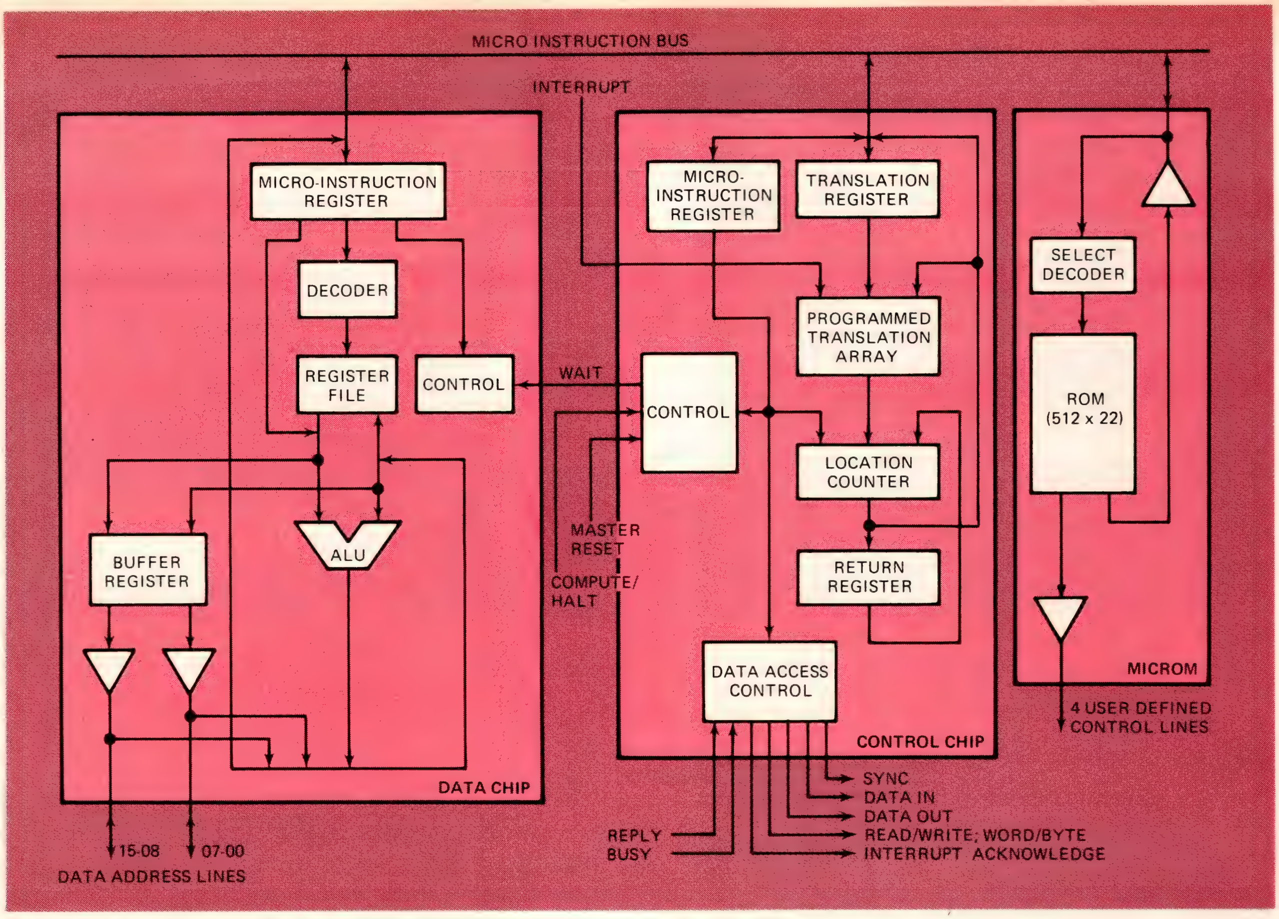

Fig. 3—This 3-chip set is derived along classical computer lines: The data chip handles all I/O and computations; the control chip decodes the macroinstructions, provides microprogram control, and controls external interfaces; and the microprogram ROM (MICROM) provides permanent storage for microinstruction routines.

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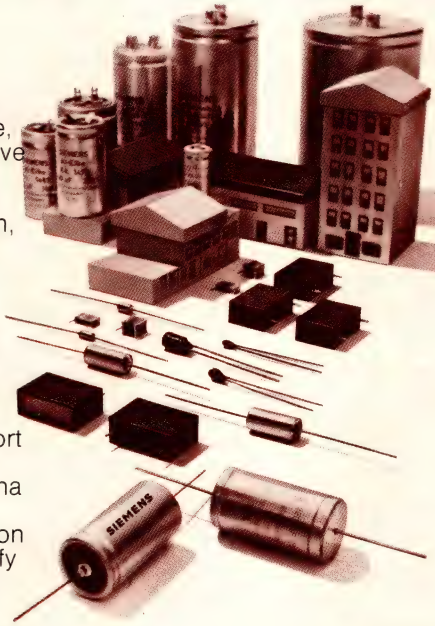

functions and (2) a flexible and comprehensive microinstruction repertoire. In this case, the MCP1600 can operate with a 300-nsec microinstruction cycle accomplished by "pipelining," or fetching the next microinstruction while still executing the present one (also called look-ahead). The instruction set includes 84 basic microinstructions with operator selection of byte or word operations, source and destination registers, ALU flag updating and branch conditions that allow over 50,000 permutations and emulation of nearly every processor's macroinstruction set and address modes.

When the PTA does not generate linkage jumps between microinstructions, but instead provides for sequential processing, the device acts as a microcontroller. In such a case, the machine can be programmed to perform a fixed set of operations at a rate of up to 3.3M microinstructions/sec. Programs can be stored in MICROM or random-access memories to allow highly efficient, dedicated and customized processor performance.

Simplicity provides the best solution

Both microcontrol and emulation provide good examples of the power that microprogramming gives the designer—essentially his ability to create improved macroinstructions. This link between software and hardware offers the advantage of machine redesign through programming, while maintaining control at an efficient hardware level. □

Author's Biography

Gary DesRochers, a Senior Application Engineer with Western Digital Corp., earned his BSEE from California State University at Long Beach and his MSEE in computer science from USC. Among his accomplishments is the development of a MOS microprocessor and other special-purpose computers and computer interfaces. Gary is also interested in home computer development.

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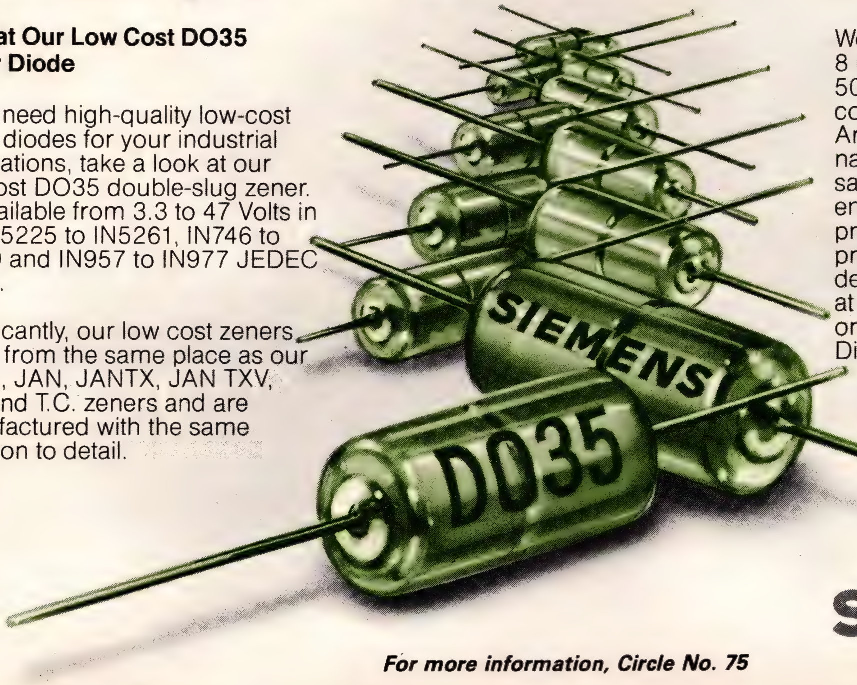

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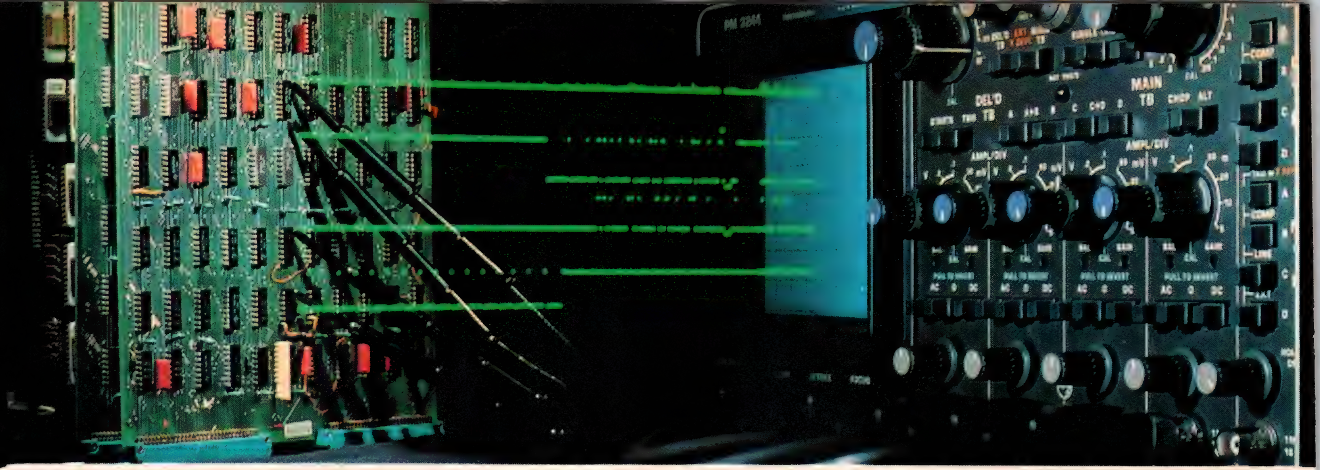
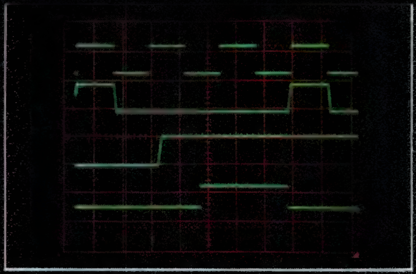
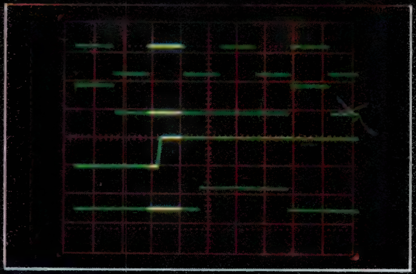


Four 50 MHz channels. Unique triggering facilities. Ideal for parallel data analysis.

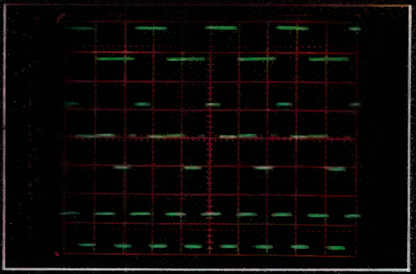
Zero in on



As illustrated on the front panel detail, triggering is fully independent and multi-sourced. This gives a number of unique triggering possibilities and is just as useful for more conventional dual-trace measurements.



Here the main and delayed timebases are triggered from different channels, one example of the PM 3244's unique triggering facilities. Signals can therefore be shown even when they are not related to the main timebase.



Differential measurements can be made on the PM 3244 in the conventional manner or by using the composite triggering mode.

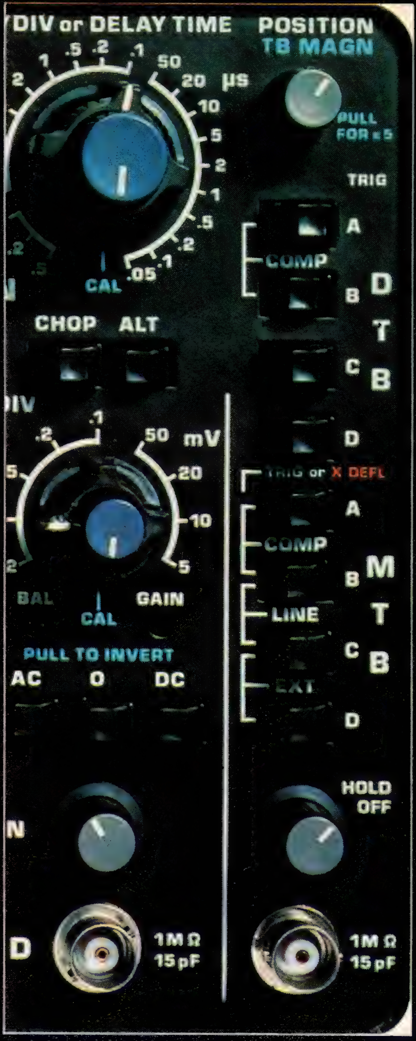
Four traces give you the logic story: show the relationships at a glance. But only the PM 3244 gives you four traces and fully independent triggering of main and delayed timebases. Thus the main timebase can be triggered on any of the four channels plus composite, external and line. The delayed timebase can be triggered on any of the four channels plus composite: independently! This gives a number of unique triggering possibilities, for example showing relationships that are not directly related to the main timebase, like the information in a data line when the main timebase is triggered on an address line.

Doubles for dual-trace with *extra* performance.

PM 3244 is the world's first four-channel compact and all channels have full display facilities i.e. sensitivity, attenuation, invert, etc. It can therefore be used to make isolated or differential measurements and when you need conventional dual-trace displays, this scope also gives them, with two traces in reserve plus unmatched triggering facilities.

All displays are on a large 8 x 10 cm screen and the compact construction weighs in at a mere 9.6 kg (21 lb). The price is rather compact too!

Write for more details. Read opposite about another data breakthrough.



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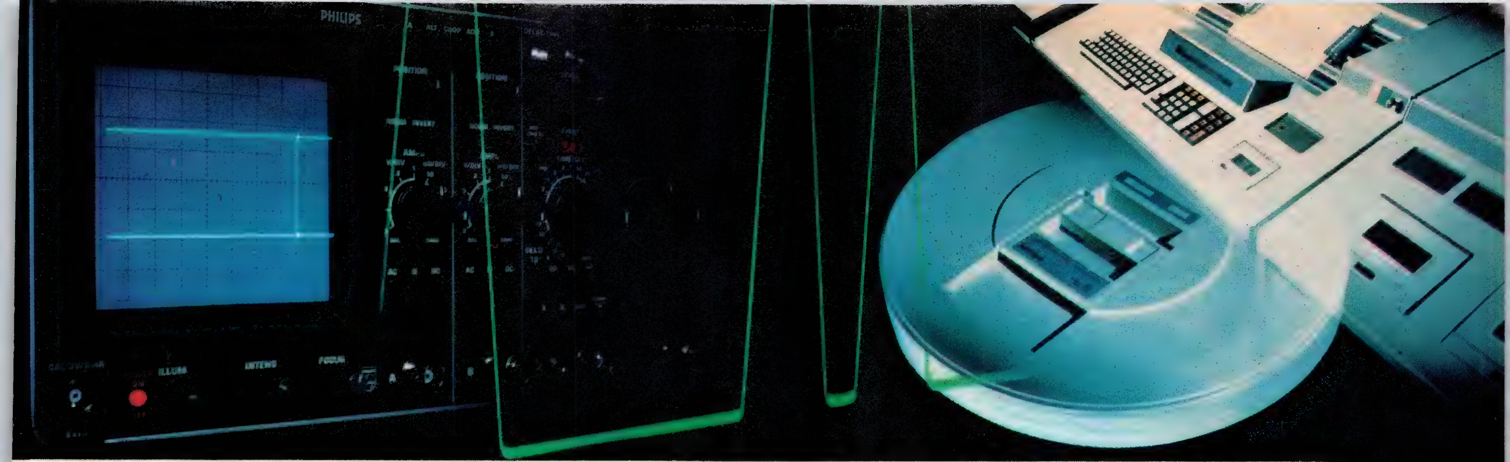
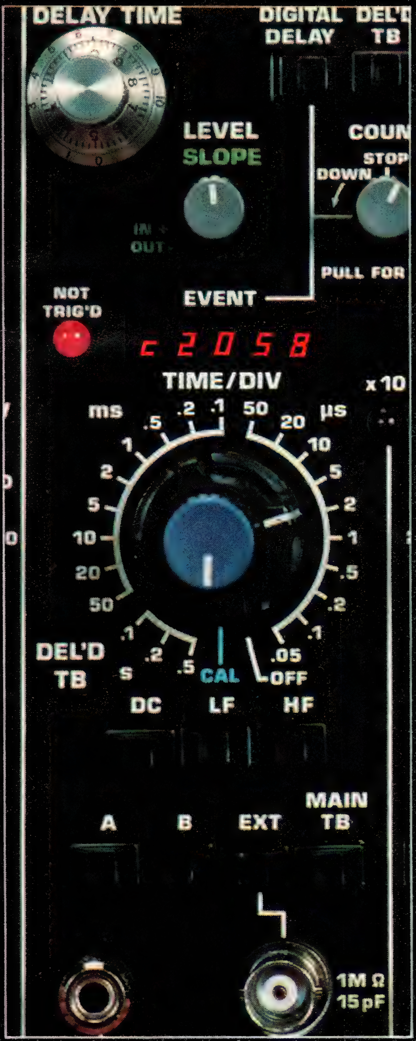


120 MHz with digitally delayed triggering to over 200 MHz. Ideal for serial data.

ones and zeros

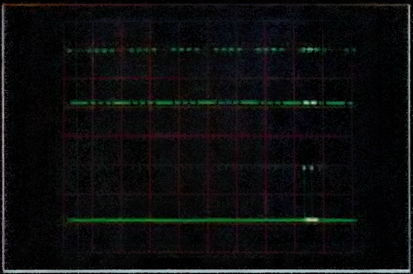


The PM 3261 is another world first. In addition to conventional triggering facilities, the instrument features a digitally delayed timebase that can be set to trigger on a particular pulse in a data stream, the position being displayed on the built-in, five-digit LED. This facility allows individual events to be located quickly and accurately in data streams of up to 100,000 bits and then be 'trapped' for detailed display.

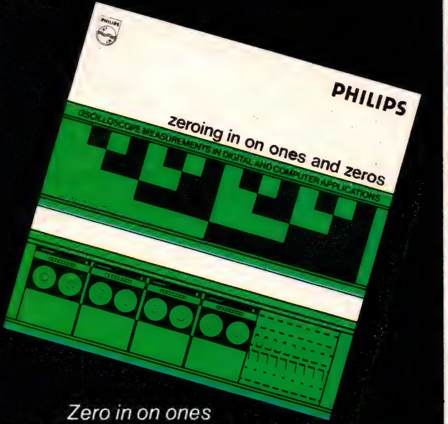
The event is located using the illustrated delay counter, which can be set to count up or down at an adjustable speed as low as one step every two seconds. Specific sections can thus be examined and the counting stopped and stepped back to pick up and locate any irregularities.

The digitally delayed counter also overcomes problems of jitter, such as occur in mechanical systems like disk memories, tape drives, etc. In such cases, if the jitter is longer than one period, a conventional delayed timebase cannot be effectively employed. Once that display has been trapped, accurate time interval measurements can be made using the normal delayed timebase controls.

In addition, the main timebase has a TTL triggering facility to eliminate triggering problems on preshoot, overshoot, ringing, etc.



As illustrated on the front panel detail, one push button and one control knob are all that's needed to operate the digital delay. The required event in the data stream 'lights up,' as shown, and can then be displayed using the normal delayed timebase in order to make accurate time interval measurements.



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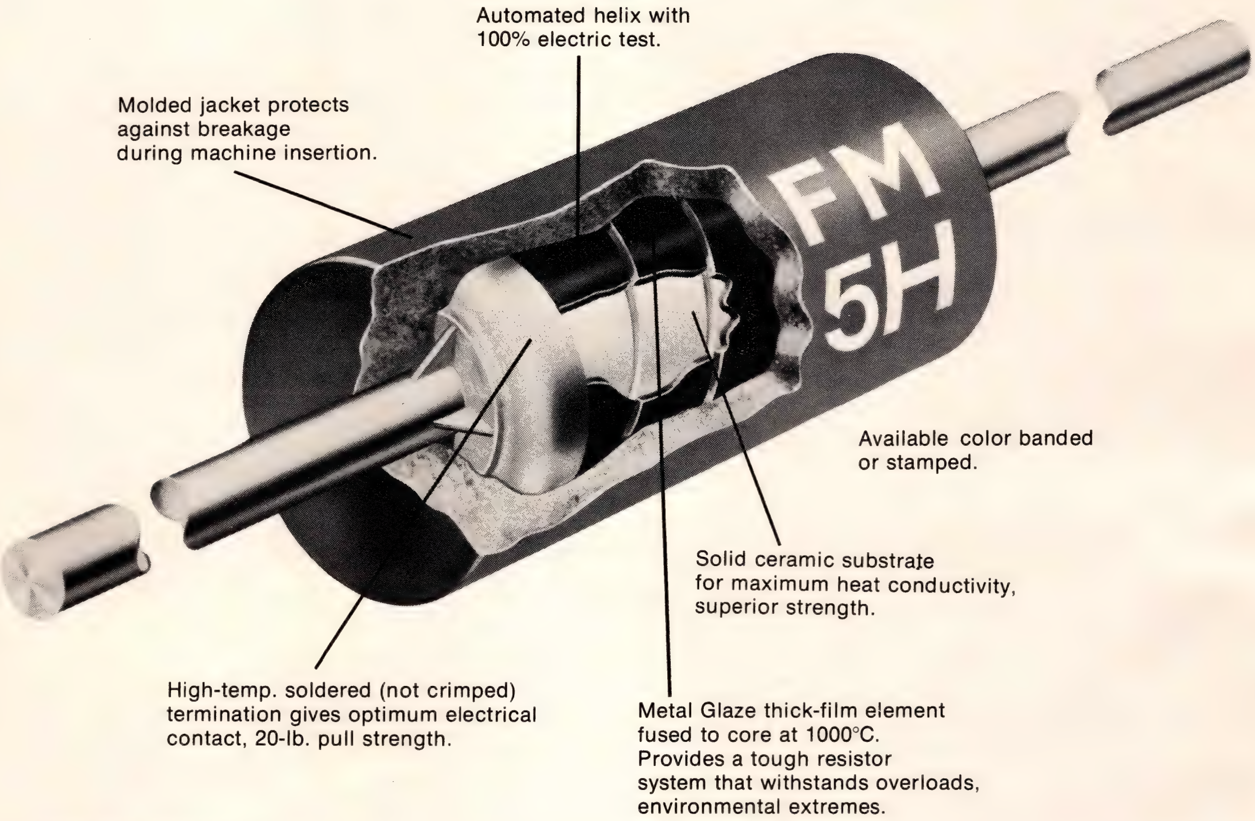
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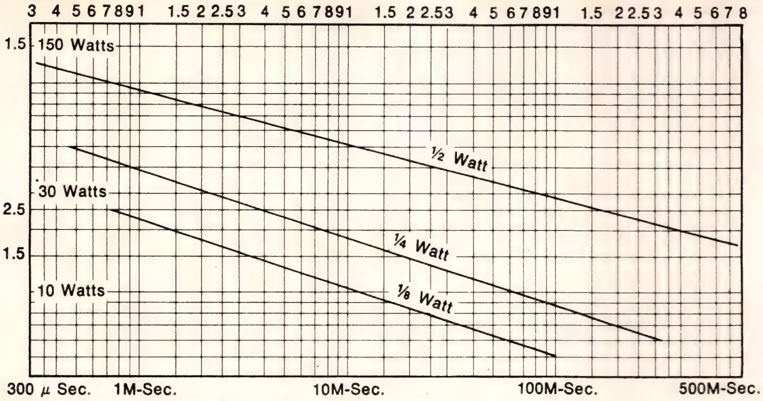

Note: Average power dissipation not to exceed component rating.

Overload Protection

Rugged Metal Glaze construction provides excellent power surge capability. A ¼w unit will conservatively operate within specifications when exposed to 18w, 10msec pulses, provided average power, and max voltage ratings are not exceeded. Ask us about your applications, including those requiring steady state conditions exceeding mil rated power.

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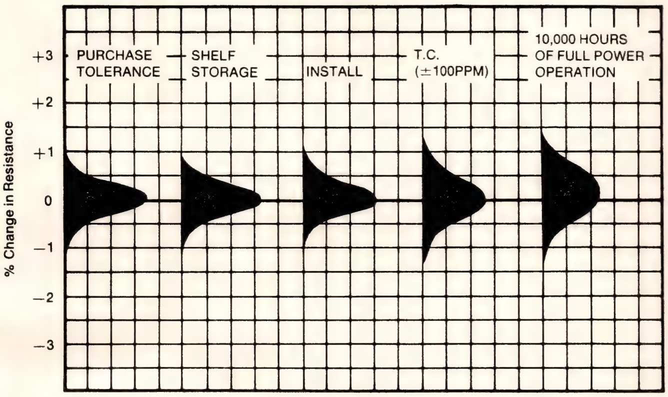
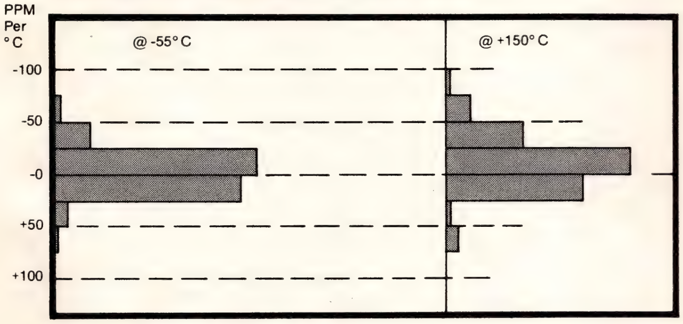


Minimum Design Tolerance

(Design tolerance = a statistical summation of various parameters including load life, TCR, installation, and moisture resistance) All the features of Metal Glaze Resistors result in tight, predictable design tolerances which can be as low as ±1.5%, depending upon your application.

TYPICAL DISTRIBUTION OF
TEMPERATURE COEFFICIENT OF RESISTANCE



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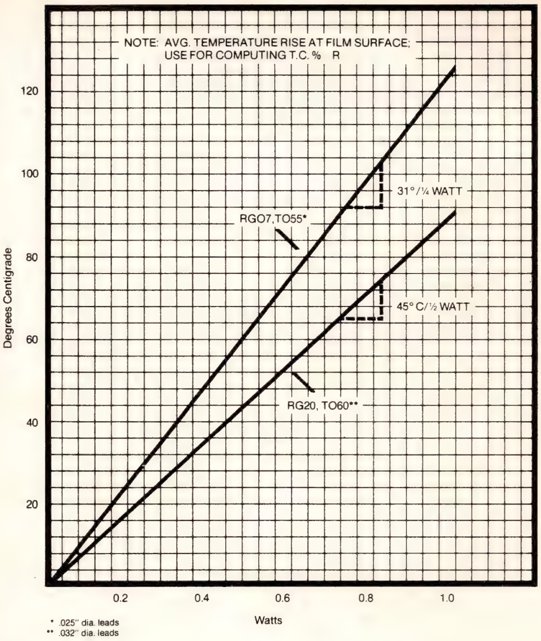

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A solid alumina substrate and other design features efficiently transfer heat from the resistor element. As an example, a ¼w unit at full load has a hot spot temp rise of only 30°C, half the rise experienced in some other types. Cooler operation means stability and reliability are optimized.

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All Metal Glaze resistors have our exclusive high temperature soldered terminations. This capless construction means excellent pull strength and prevents substrate damage during assembly. With the additional protection of a molded jacket, 1/4w Metal Glaze resistors withstand a 20lb pull test.

TRW IRC RESISTORS

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DESIGN AWARDS

Sharp null filter utilizes minimum component count

Robert Carter
Arnold AFB, Tennessee

Constructed around a low-gain quad op amp and suitable for single-ended supplies, this circuit configuration provides the sharpest null attainable with the least frequency-determining number of parts.

IC_1 gives the filter (IC_2) a low driving source impedance, but you can insert a potentiometer into the feedback impedance (ganging this potentiometer with the existing pot **(Fig. 1)** to compensate for the $\frac{1}{x}$ factor in the transfer function).

As regards transfer functions, my active filter rejects frequencies of the form $f_0 = 1/2\pi T$ or $1/2\pi RC$. With the pot at the 1/3 clockwise setting, the circuit gives the transfer function:

$$G = \frac{e_o}{e_1} = -\frac{1}{3}\left[\frac{T^2 s^2+1}{(Ts+1)^2}\right]$$

At the full clockwise setting, the transfer function essentially becomes unity and frequency independent. You can vary the depth of the rejection notch by intermediate settings of the pot between 1/3 and full clockwise. This way, you can express the transfer function as:

$$G = \frac{e_o}{e_{in}} = -\frac{1}{x}\left[\frac{T^2 s^2 + (3-x)\,Ts+1}{(Ts+1)^2}\right];\ 1 \leq x \leq 3$$

At the full counterclockwise position the transfer function becomes:

$$G = \frac{e_o}{e_{in}} = \frac{+\,Ts}{(Ts+1)^2}$$

which gives a peaked response at f_0 with −6 dB gain. □

To Vote For This Circuit
Circle 326

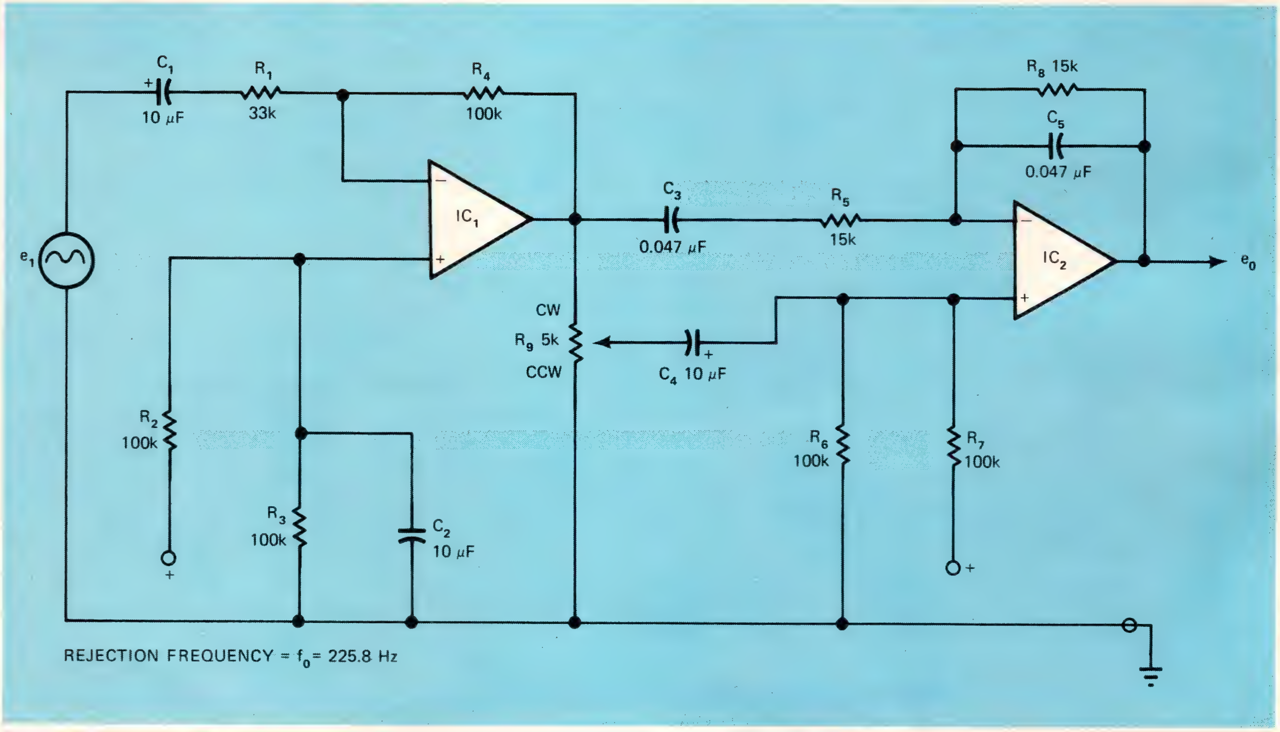
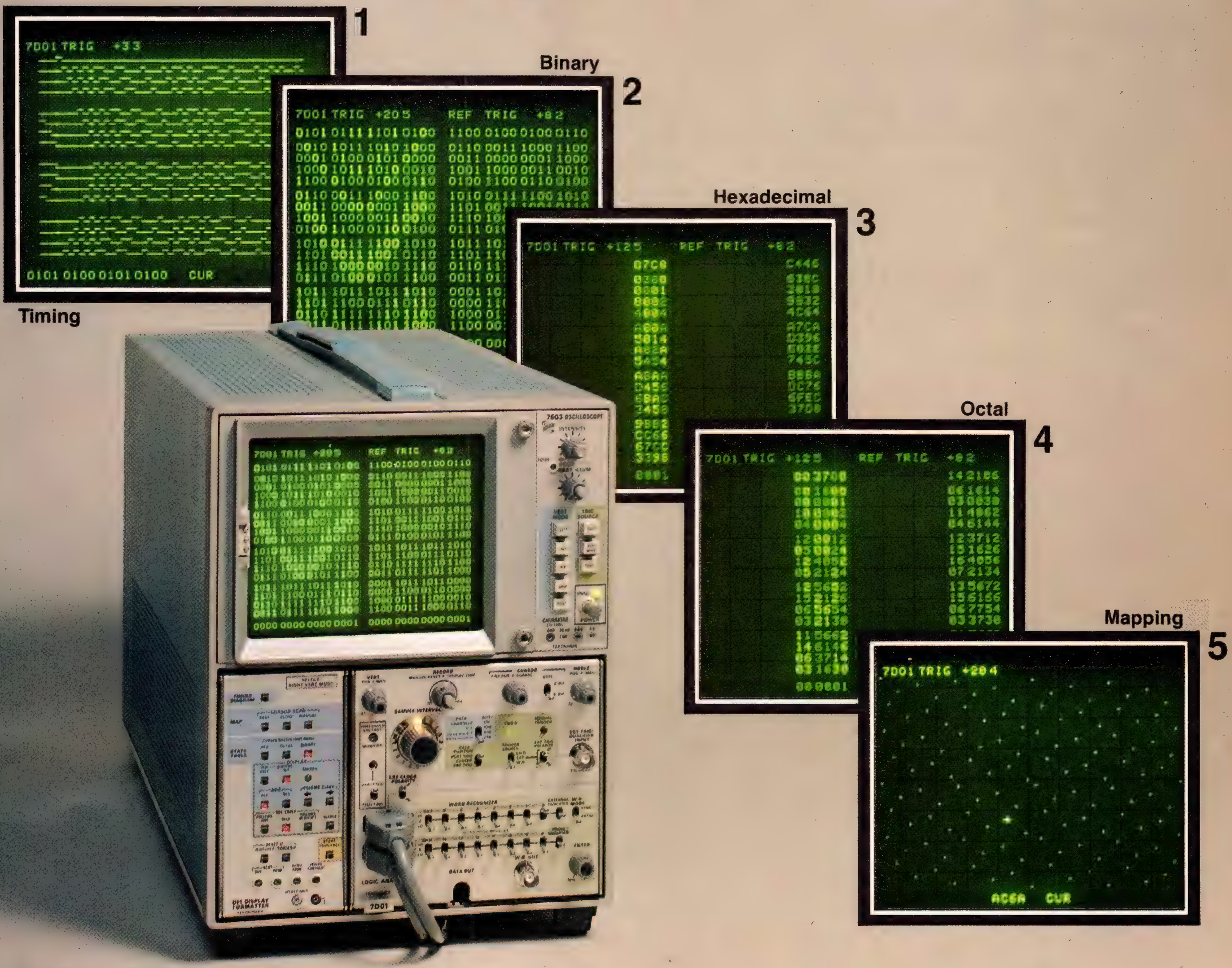


Fig. 1—Active rejection filter produces an extremely sharp, depth-adjustable "notch," yet uses only a small number of low-cost parts.

TEKTRONIX now has 5 ways to look at logic.



The New DF1 Formatter

First, we gave you the timing display and binary readout with our 7D01 Logic Analyzer. *Now,* with the DF1 Display Formatter, which is dedicated to the 7D01, you have five display formats to operate from, all in a 7000-Series mainframe. Now you can convert a timing display into tables of words in Binary, Hexadecimal, Octal ... or a mapping configuration ... whatever your application requires.

A STATE TABLE mode of operation produces standard tables of up to 16 lines of 16-bit words. Using the 7D01's cursor, you can step through these tables word-by-word in Binary, Hex, or Octal. A 17th word is added to each table emerging from the 7D01's memory, to serve as a "key" and indicate you are indeed scrolling correctly through the long memory. The 7D01's fine cursor control steps the display line-by-line, while the coarse control advances it table-by-table.

One of the most powerful analytical capabilities provided by the STATE TABLE mode is that you can display *two* tables–a reference table of "proved" data plus a "new" data table drawn from a system under test–on the same crt for side-by-side comparison. New data that is different from the reference data is automatically intensified ... you immediately know faulty data exists, and you know its location.

With the DF1 you can map, not just one, but three ways. The ability to map FAST, SLOW, or MANUAL lets you quickly recognize a word of interest, track it, isolate it, then pinpoint it for detailed analysis. The importance of mapping is derived from the speed with which you can isolate problems.

The logic analyzer package shown (7603 Option 1, 7D01, DF1) starts as low as $5790. If you already own a 7000-Series mainframe, add the 7D01-1 (7D01/DF1 combination) for only $4390. Also consider that your money buys you these important 7D01 features: 1) Word recognition, 2) 16 channel operation, 3) 15-ns asynchronous timing resolution, 4) 4k formattable memory (4, 8 or 16 channels), and 5) High Z probes.

For more information or a demonstration of the DF1, contact a Tektronix Field Engineer near you. Or write Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077.

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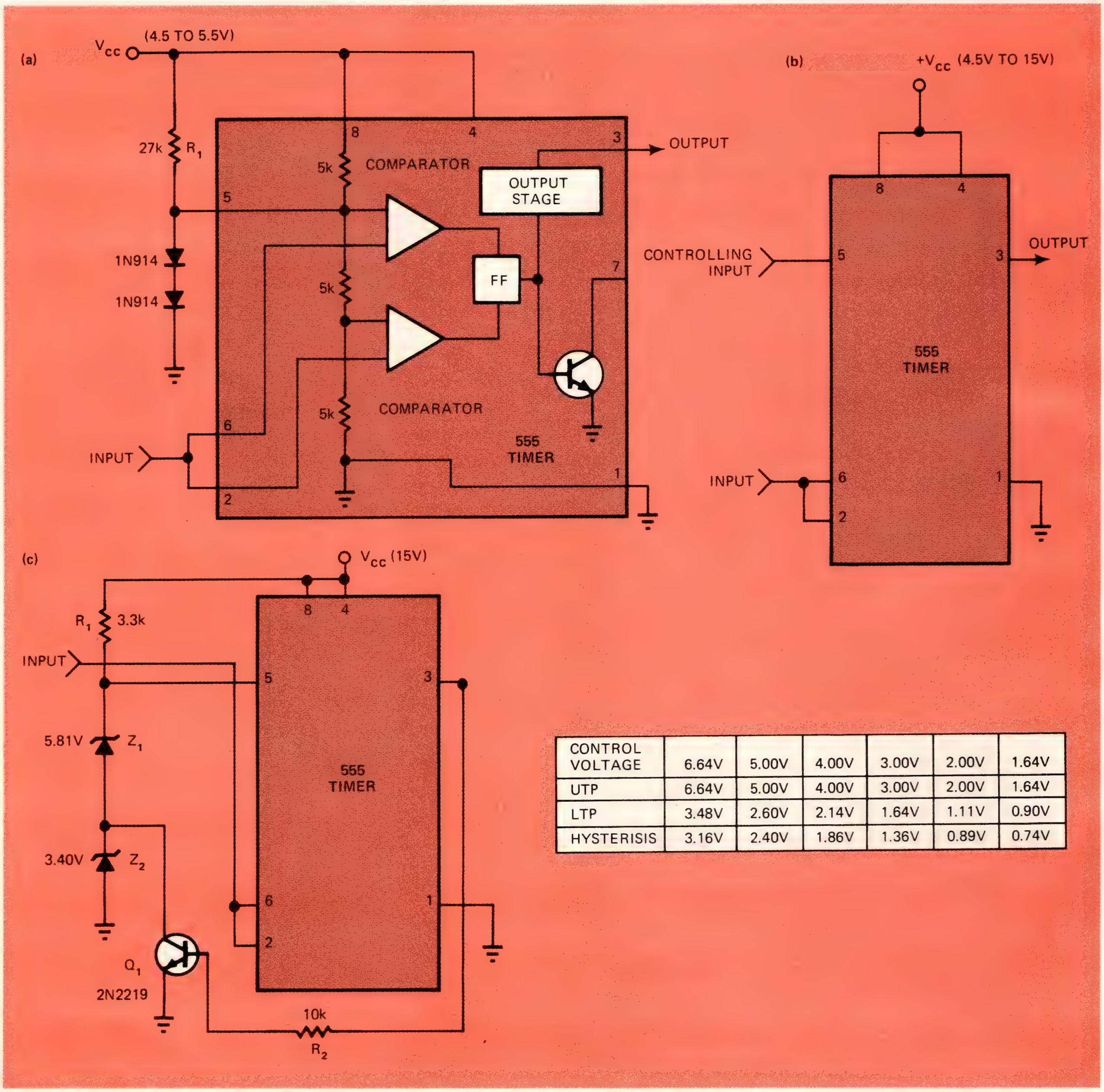
Variable-threshold Schmitt trigger uses 555 timer

M.K. Lalitha and P.R.K. Chetty
ISSP, Bangalore, India

With a 555 timer and a handful of parts, you can build a fully TTL/DTL-compatible Schmitt trigger, capable of being triggered from straight dc levels or the slowest input ramps, while still giving clean and jitter-free output.

In **Fig. 1a** we've connected the timer as a straight TTL-compatible trigger. Examination shows the control-voltage terminal connected to a voltage produced by two forward-biased silicon diodes (approximately 1.35V). Internally, this voltage hits one of the 555's two internal comparators directly and at the same time is divided by the timers' "inside" 5k resistor pair for application to the second comparator.

How does this trigger work? With the output initially HIGH, you can increase the input voltage from >0 to <1.35V without driving the output LOW. When you reach 1.35V, however, this will occur. Conversely, the input can decrease until it reaches a value of about 0.7V at which point the output returns to the HIGH state. Thus, the hysteresis equals about 0.65V. We've assumed that your supply can vary between 4.5 to 5.5V as in the case of 7400 series logic. But those pinching



CONTROL VOLTAGE	6.64V	5.00V	4.00V	3.00V	2.00V	1.64V
UTP	6.64V	5.00V	4.00V	3.00V	2.00V	1.64V
LTP	3.48V	2.60V	2.14V	1.64V	1.11V	0.90V
HYSTERISIS	3.16V	2.40V	1.86V	1.36V	0.89V	0.74V

Fig. 1—How do you like your Schmitt Trigger? Once again, the "toolbox-on-a-chip" 555 finds use as **(a)** a straight TTL/DTL-compatible trigger, **(b)** a variable threshold-type unit and **(c)** an independently variable hysteresis Schmitt trigger.

The Raytheon 2900 family gains five new members

Whereas: Raytheon is the established alternate source for the Am2901 and Am2909, (franchised distributors stocked), and,

Whereas: Raytheon brought you RAYASM, the powerful micro-assembler available on the NCSS computer network,

Now Therefore: Raytheon announces five additional 2900 family components, giving us a total of seven, To Wit:

2901 A 4-bit Microprocessor Slice—the fastest, most powerful LSTTL microprocessor in the world. With its cycle-saving two-address architecture, the 2901's speed can't be touched.

2905 A 4-bit Bus Tranceiver— general purpose open collector bus interface device. Data to the 100 milliampere bus drivers is provided by a 4-bit register with a two-way multiplexer at its inputs. Data from the bus receiver may be held in the 4-bit receiver latch on its way to the three state receiver outputs.

2906 A 4-bit Bus Transceiver with parity —is equivalent to the 2905 but with the addition of an on-chip parity generator/checker.

2907 A 4-bit Bus Transceiver—similar to the 2906 with the two-way multiplexer at the input to the bus driver register eliminated to allow the device to be packaged in the space saving 20-pin DIP.

2909 A Microprogram Sequencer—that can branch anywhere in memory, perform sub-routines, then return with up to four levels of sub-routine nesting. The device is a cascadable 4-bit slice which allows addressing of up to 4K words of microprogram with three devices.

2918 A General Purpose 4-bit Register—with two sets of outputs: TTL and three state. This useful combination can reduce your package count for those status, command, and instruction registers which must drive both your control logic and a data bus.

93415 A 1024 × 1-bit Fully Decoded Random Access Memory—for your high-speed data and control stores.

Raytheon LSI is on the move. More 2900 family components soon to come include PROM's, sequencers, look-ahead carry generators, additional RAM's, and other goodies now in process.

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pennies can get away without the 2.7k resistor, providing the diodes saturate with the current delivered by the 555's internal resistance.

In **Fig. 1b** we've connected the trigger to produce a variable, controlling-input voltage (CIV) function. The TABLE shows the tripping points for various CIV's. Notice that the lower threshold point (LTP) is nearly half the inherently fixed upper threshold point (UTP).

In **Fig. 1c** we've rigged a variable-hysteresis version of the trigger. The circuit operates as follows: If the input equals ZERO, the output goes HIGH causing transistor Q_1 to turn ON. Thus, the CIV terminal catches a voltage equal to $[V_{CE}sat(Q) + V_{Z1}]$ (UTP) where V_{Z1} is the voltage rating of zener number one. As the input voltage increases, the output falls LOW (at the UTP) and Q_1 turns OFF. Hence, the voltage at terminal 5, for the present at least, equals $V_{Z1} + V_{Z2}$. Since about half this voltage hits the second comparator, the LTP will approximately equal $(V_{Z1} + V_{Z2})/2$. By choosing various zeners you can easily control the threshold points to suit your taste. For the circuit shown, we've selected a LTP of 4.7V and an UTP of 5.8V. □

To Vote For This Circuit
Circle 327

Counter pre-amp matches CMOS logic capability

Ralph Tenny
Texas Instruments, Dallas, TX

Thanks to the digital revolution, most field engineers or service technicians would gladly welcome a truly portable, long battery-life frequency counter. But present units, built mainly around CMOS logic, generally have one major shortcoming: The circuitry used to condition the input waveforms; i.e., the amplifier/Schmitt trigger circuitry, doesn't provide CMOS-compatible frequency response, sensitivity or power consumption (**Ref. 1-3**).

However, this circuit combines the CA3130 and CD4010 devices and proves to have sufficiently broad frequency response at very low power levels **(Fig. 1a).** Combining PMOS, bipolar and CMOS technology on the same chip, the CA3130 yields high slew rate with low power. Note that in the circuit shown, I've hooked the output to 1/6 of a 4010 buffer—the result acts as an operational or Schmitt trigger **(Ref. 4).** Also note that two diodes protect the input from overvoltage and that I've used the amplifier offset control as a front-panel, trigger level control.

Input sensitivity of the amplifier/trigger combination equals 50 mV p-p from 1 Hz to 1 MHz; with 100-mV input, performance extends to 1.5 MHz. For period and time-interval measurements with digital (fast rise time) waveforms, the circuit will produce start/stop triggers from very low frequency sources.

Alternatively, a dc-coupled circuit is also feasible **(Fig. 1b).** The only restriction on dc operation is to keep the output impedance of the frequency source sufficiently low (50 kΩ or less) to minimize noise pickup.

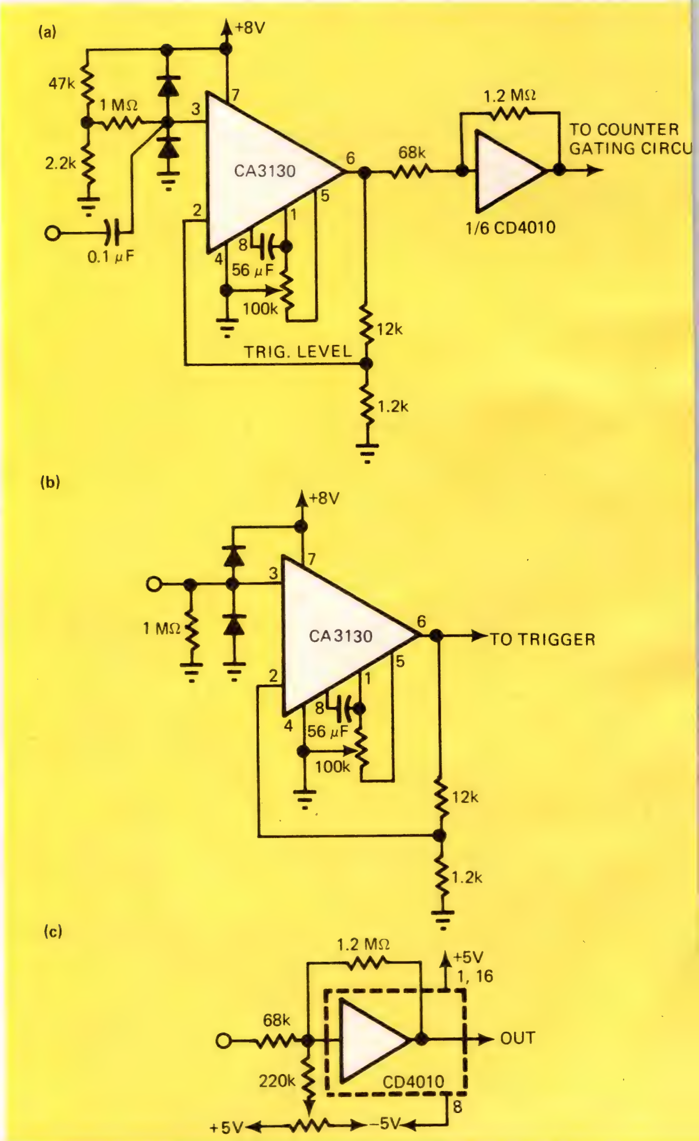

Fig. 1—Waveform conditioning circuitry provides the low-power/frequency-response characteristics demanded by the CMOS logic family.

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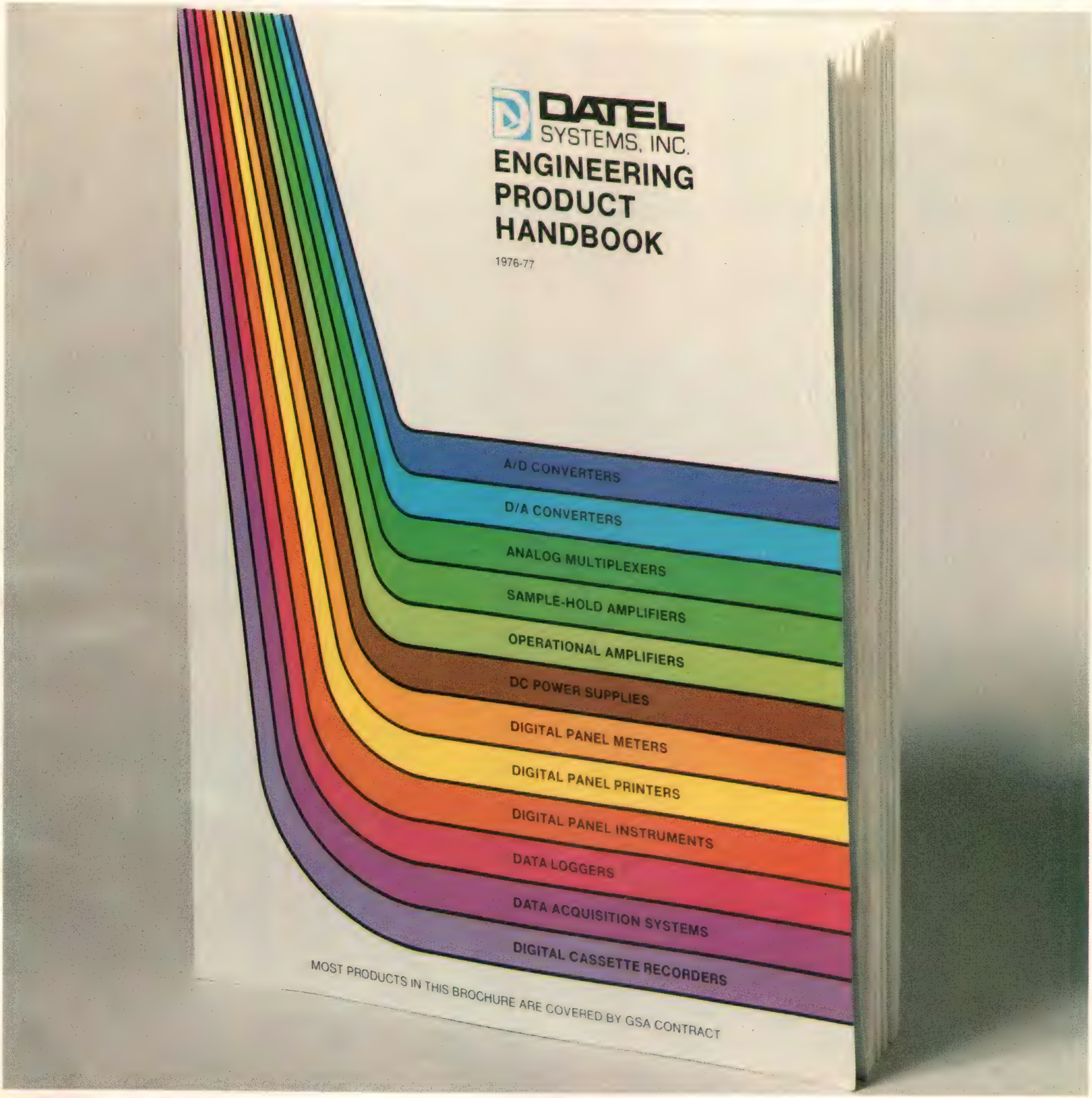

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Finally, **Fig. 1c** shows a simpler input. If you operate the counter circuitry from 5V, the trigger level control will give optimum centering to permit dc to 3-MHz operation at 100 mV p-p.☐

References

1. *"EDN CMOS Design Course—Part 1," EDN, Nov. 1, 1972, pg. 20.*
2. *"CMOS finally gets it all together," EDN, June 15, 1972, pg. 28.*
3. *"CMOS counter circuitry slashes battery power requirements," EDN, Oct. 20, 1974, pg. 65.*
4. *"Reduce system noise with CMOS circuits," ELECTRONIC DESIGN, Dec. 6, 1973, pg. 112.*

To Vote For This Circuit
Circle 328

Eight-bit frequency source suited for µP control

Albert Helfrick
Kay Elemetrics Corp., Pine Brook, NJ

The need for a digitally programmable frequency source usually brings to mind the phase-locked loop. In systems under microprocessor control, however, it's necessary to insure that the phase-locked loop has settled to the frequency desired before accepting data. In the digitally controlled frequency source described here, the frequency change is virtually instantaneous, assuring immediately valid data.

A MC1408L8 8-bit monolithic D/A converter,

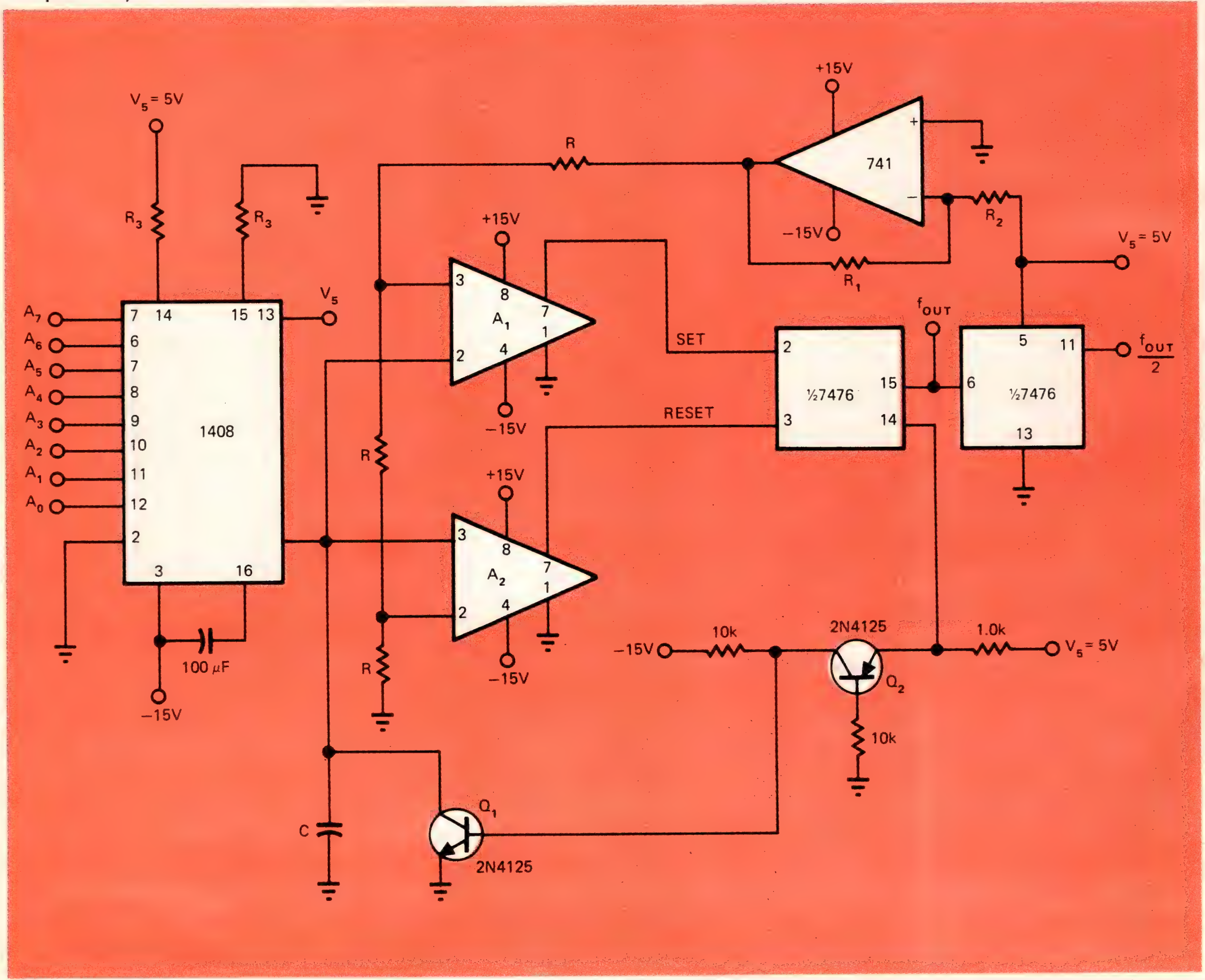

Fig. 1—Digitally programmed frequency source employs a monolithic 8-bit D/A converter to supply the constant-charging current.

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the heart of this system, supplies a constant current for charging the capacitor, C (**Fig. 1**). Since the output current of the D/A is negative, the capacitor voltage becomes more negative (linearly) until it exceeds the lower threshold voltage at pin 3 of the comparator, A_1. This comparator changes state and sets the set/reset flip-flop; the clear and preset inputs of one-half a 7476 JK flip-flop serves this purpose. The flip-flop then turns on Q_1 through the level shifter, Q_2, which quickly discharges capacitor C until it exceeds the higher threshold voltage at pin 2 of A_2. This comparator switches the set/reset flip-flop back to its original state, thus allowing the capacitor to charge again.

The 741 op amp inverts and amplifies the supply voltage. The voltage as applied to the resistive voltage divider, consisting of the three R's, equals $-V_5\ (R_1/R_2)$. The upper and lower threshold voltages are $(-V_5/3)\ (R_1/R_2)$ and $(-2V_5/3)\ (R_1/R_2)$ respectively. Since the reference current for the D/A is also a function of the 5V supply, i.e., $-V_5/R_3$, all dependence of the output frequency on supply voltage is eliminated and the output frequency equals:

$$F_{out} = \frac{3R_2}{512(R_3R_1C)} \begin{array}{l}(128A_7 + 64A_6 + 32A_5 + 16A_4 \\ +8A_3 + 4A_2 + 2A_1 + A_0)\end{array}$$

where $A_7 \ldots A_0$ sit either LOW or HIGH and provide the bits of the digital input.

Discharge time of the capacitor is very short as compared to the charge time. Therefore, the waveform at the output of the set/reset flip-flop (F_{out}) has a very small duty cycle as well. Since this may be undesirable, the remaining half of the 7476 functions as a divide by two, supplying a second output, $F_{out}/2$.

Typical circuit values for a 10- to 2550-Hz source at the F_{out} terminal with 10-Hz resolution are: $R_1=27k$, $R_2=10k$, $R_3=2.2_k$, $C=0.1\ \mu F$ and $R=3.9k$.

For true 8-bit accuracy and resolution over temperature, remember to choose the components carefully. The capacitor, C, may be of the plastic-film type such as polypropoleyne or polycarbonate. The resistors should be temperature stable but not necessarily precision type. Finally, you should use high-impedance comparators such as the LM311. ☐

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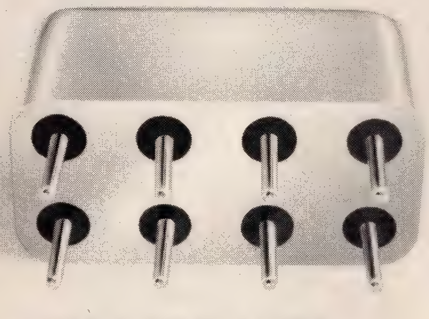
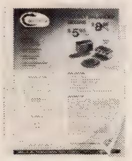
Circle 329

New low cost DC-1 GHz doubly balanced mixers

CM-1 CM-2



CM-1, DC-500 MHz



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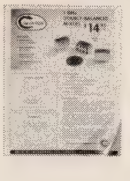

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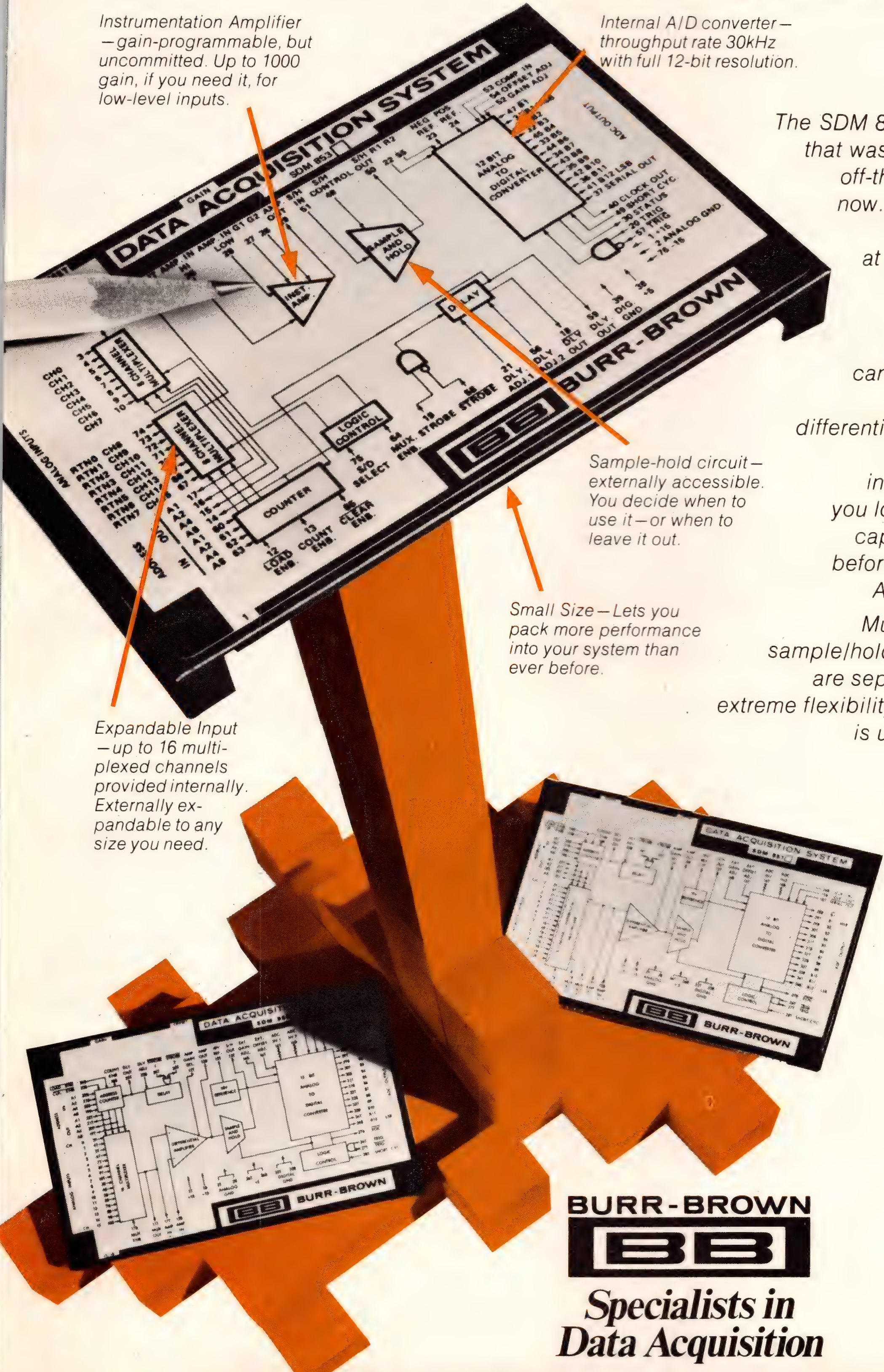

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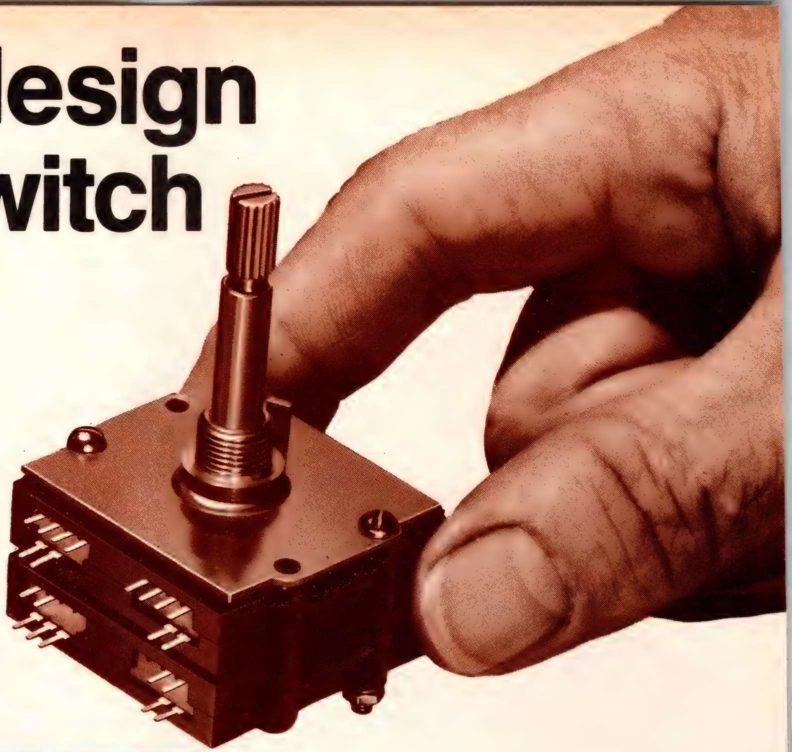

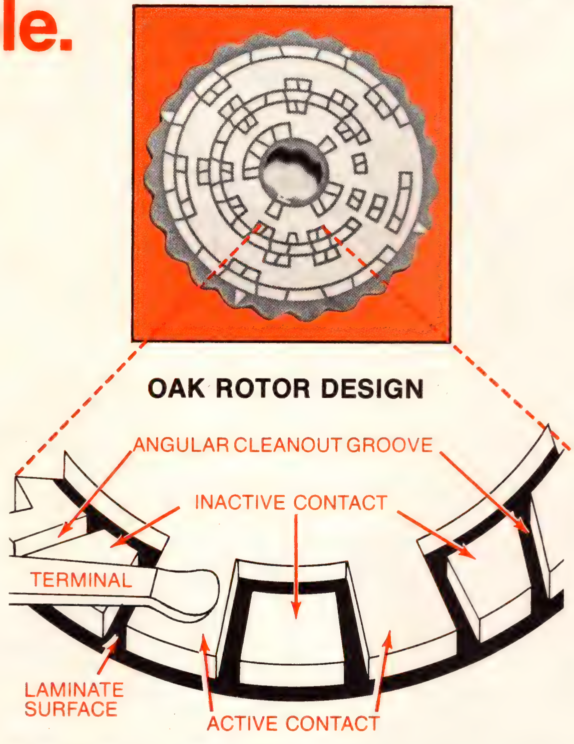

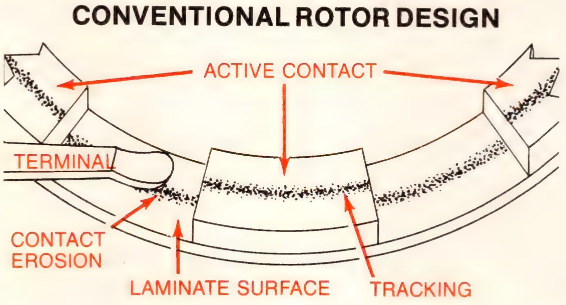

The Oak Communicator Series switch features a patent-applied-for rotor design for long term contact registry and integrity. Programming is accomplished on a metal-clad, laminated rotor of exclusive construction.

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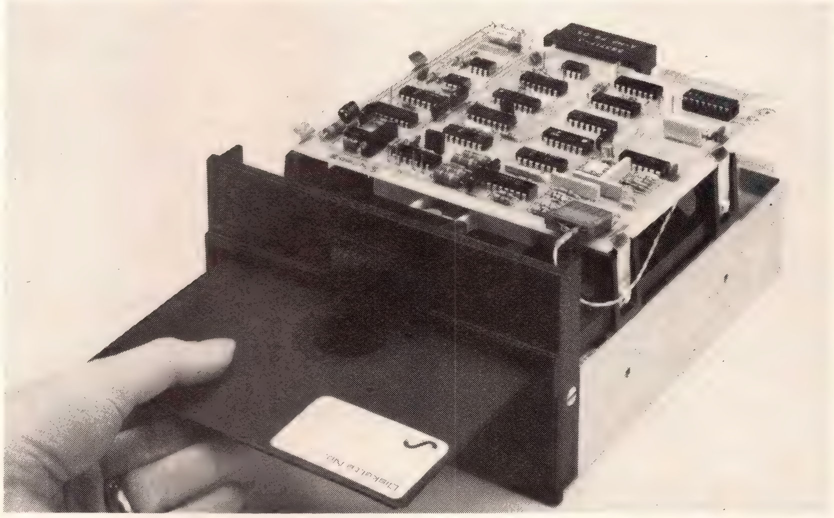
Mini floppy disc solves size and cost problems in μP applications

PROGRESS IN COMPUTER PERIPHERALS

A miniature version of the already small floppy disc provides users with a recording medium competitive in size and cost with cassettes, while retaining the speed, performance and reliability features of a standard floppy disc. First available drive for this new Minidiskette™ is the SA400 Minifloppy™ disc drive from Shugart Associates, the largest independent supplier in the field.

The small size (5.75×3.25×8 in.) and low price ($250 in 500-piece volume) make the Minifloppy drive ideal for μP applications, including instruments, high-end calculators, program storage and hobby computers.

Like the larger floppy drives, the SA400 is loaded by simply sliding the diskette through the slot in the front panel and then closing the cover. Unless the diskette is properly seated, an interlock inhibits door closure, thus preventing damage to the medium.



Minidiskette, only 5-1/8 in. in diameter, makes possible a floppy-disc drive competitive in size and cost with cassette decks.

1/3 the capacity, 1/2 the speed

The 5-1/8-in. Minidiskette resembles its larger brothers, being a tough mylar disc with magnetic-oxide coating on both sides. Supplied in a 5.25-in.^{2} envelope, this small disc has a capacity of 80 to 90k bytes formatted and 110k bytes unformatted. While its transfer rate (125k bps) is half that of the standard diskette, it is low enough to interface with the popular 8080 μP without need for direct memory access.

The unit also features 100-msec average latency, 566-msec average access time, 2580-bpi recording density using FM encoding and 48 tracks/in. Both soft- (SA104) and hard- (SA105) sectored discs are offered, with 16 physical sectors for the SA105. Disc life is specified at 3×10^6 passes/track.

COMPARISON OF POPULAR LOW-COST MASS-STORAGE SYSTEMS

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HEADS	1	1	1	4
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RECORDING DENSITY/TRACK (BPI)	2600 MAX.	3200	800	1600
AVERAGE ACCESS TIME (SEC)	0.566	0.286	20	20
TYPICAL DRIVE SIZE (IN.)	3.25 x 5.75 x 8.0	4.62 x 8.55 x 14.25	4 x 6 x 8	4 x 6 x 8
TYPICAL WEIGHT (LB)	3	14	5	5
TYPICAL DC POWER REQUIREMENTS (V)	5, 12	−15, 5, 24	± 12, 5	±12, 5
DRIVE PRICE (QUANTITY 1)	$390	$600	$500	$500
MEDIUM SIZE (IN.)	5.25 x 5.25	8.0 x 8.0	4 x 2.5 x 0.4	4 x 6 x 0.67
MEDIUM PRICE (QUANTITY 1)	$4.50	$6.50	$8	$20

NOTE: AVERAGE ACCESS TIME = AVERAGE SEEK TIME + AVERAGE LATENCY TIME

Interfaces like a standard disc

Shugart chose an interface similar to its floppy-disc interface that has become a de facto standard for the industry. This interface differs in two ways: it includes standard write protect and can turn off the drive motor from the interface connector—an attractive feature in many applications. The drive requires only standard dc voltages of +5V at 1.1A and +15V at 0.5A.

High performance designed-in

Reliability and low service requirements were major considerations in the design of the SA400. In view of the expected low price of much of the equipment that will use this drive, this latter objective was an important concern. Proven high-volume components are used with emphasis on low-stress operation.

For example, the head is the same glass-bonded ceramic head Shugart makes for its other drives. The drive motor is a commercially available dc type used for cassette recorders. Devoid of any complicated circuitry, this motor includes an internal tachometer pickup for accurate speed control. The head drive, a dc stepper motor with a unique cam positioner, is also a high-volume component being used extensively in vending machines.

Since it dissipates only 54 Btu/hr (rather than 250), the system runs cool without fans. Despite the fact that no preventive maintenance is required, the drive is rated for 8000 power-on hours of operation.

This attention to reliability results in an error rate of 1 in 10^8 soft errors—100 times better than cassettes typically exhibit—and 1 in 10^{11} hard errors that cannot be recovered.

The SA400, with electronics, sells for $390 in single quantity. A μP-based controller (Model SA4400) is also offered at a unit price of $490.

Shugart Associates, 435 Indio Way, Sunnyvale, CA 94086. Phone (408) 733-0100.

Circle No. 297

Keyboard cuts costs in half thanks to novel design and automated manufacture

PROGRESS IN COMPONENTS

Based on X-Y matrix technology developed for low-cost calculators, these standard keyboards sell for 4¢ per switch position at 100,000 pieces, and less for higher volumes. They feature a low-profile design; tactile feedback; 500,000-cycle min. lifetime; 6±2-oz actuation force; and high-quality precious-metal contacts. These units thus compete with keyboard designs costing several times more.

To use this attractive package of features, however, the designer must accept certain limitations. First, and most important, the keyboards are currently offered in 20- and 24-position versions only. No other options are available at this time. (Of course, if a user requires fewer positions, he can mask off the ones not needed.)

Second, spacing is limited to a nominal 0.5 in. However, keytops can be offset from the centers of the switches by up to 0.05 in. which does allow some arrangement flexibility.

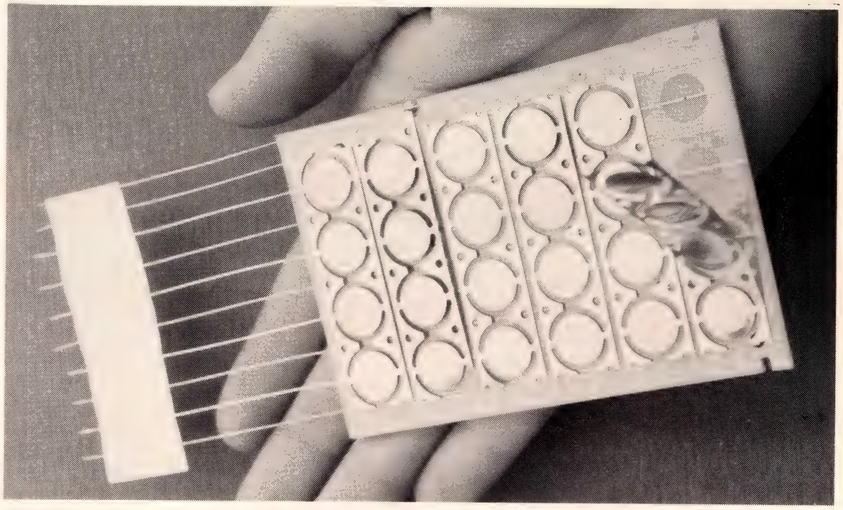
Third, electrical bounce is 6 msec, max. And fourth, the electrical format of the switch array is also standardized in the X-Y arrangement.

Thus, because the keyboard's electrical and physical matrix coincide, the user's circuits must accept X-Y switching options. In turn, this means that the keyboard must be considered early in the product design cycle—definitely before logic design begins.

Both keyboards come complete with a lead frame whose wires are arranged in a row at the top. These leads can be inserted directly into the motherboard and wave-soldered for fast assembly.

Texas Instruments Inc., Data Controls Dept., Attleboro, MA 02703. Phone (617) 222-2800.

Circle No. 298



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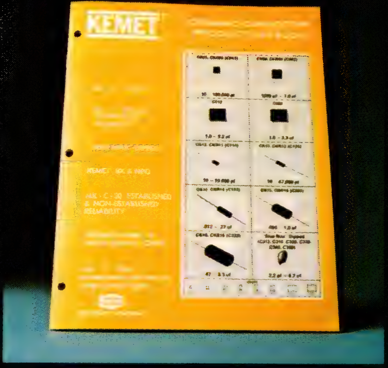

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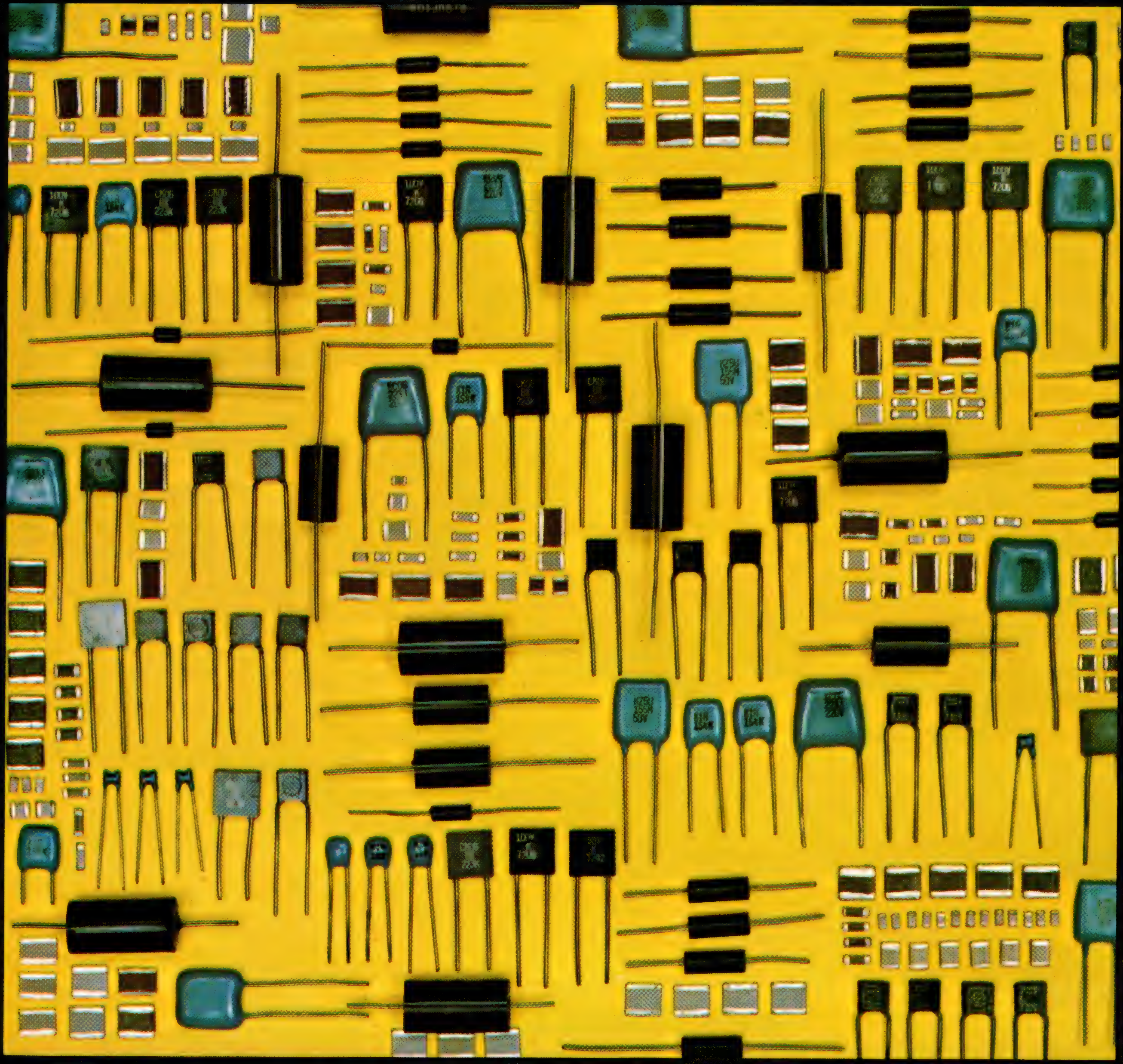

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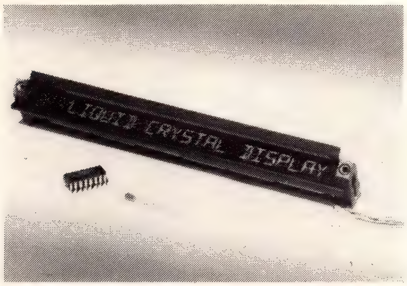
COMPONENTS/PACKAGING



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Circle No. 195

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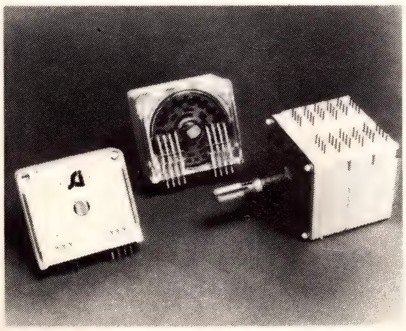

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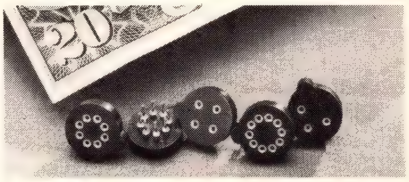
INDICATORS. The red, solid-state, status/fault indicators in the 6310 Series have a wide viewing angle from both top and front. Designed for operation on low power, these devices offer long life, good shock resistance and high reliability. Indicators can be driven from DTL and TTL, and have 0.3-in. pin spacing for DIP compatibility. The 5V, 16-mA unit comes with an internal resistor; the 1.7V, 40-mA design requires an external resistor. 70¢ (1000) and 65¢, respectively. **Chicago Miniature Lamp,** 4433 N. Ravenswood Ave., Chicago, IL 60640. Phone (312) 784-1020. **Circle No. 198**

DPM. Model 4424 is a rugged industrial-grade instrument that features a very readable high-intensity 0.6-in. display, a high-impedance FET input and a BCD output. High performance results from charge-balance (quantized-feedback) conversion techniques, and eliminating a master chip retains user flexibility. This DPM can accept a second internal pc board to provide for most signal-conditioning conversions. $135. **LFE Corp.,** 1601 Trapelo Rd., Waltham, MA 02154. Phone (617) 890-2000.
Circle No. 199

CAPACITORS. The VK family of NPO cased radial ceramic units features capacitance tolerance as low as 0.25%, and a range from 10 pF to 0.051 μF. Units are available in 3 sizes: 0.2×0.2×0.1 in. (VK20), 0.3×0.3×0.1 in. (VK30) and 0.5×0.5×0.155 in. (VK50). This line features a TC of ±30 ppm/°C, a −55 to +125°C temp. range and 50 and 100V dc ratings. Parts are offered with solder-coated copper leads, and withstand 600°F for 6 sec. $1.50 to $10 (500) with delivery 8-10 wks., ARO. **Vitramon, Inc.,** Box 544, Bridgeport, CT 06601. Phone (203) 268-6261. **Circle No. 200**



SOCKETS. Series 440 sockets are offered in 3-, 4-, 8- and 10-contact sizes. They combine precision-machined contact assemblies for reliability, with molded insulators for max. economy. These sockets also have an ultra-low profile and are available with 0.2- or 0.23-in. dia. pin circles. Insulator material is glass-filled nylon; contacts are beryllium copper with gold-over-nickel plating; and the sleeves, brass with either tin- or gold-over-nickel plating. 25¢ to $1.50. **Garry Mfg. Co.,** 1010 Jersey Ave., New Brunswick, NJ 08902. Phone (201) 545-2424. **Circle No. 201**

ROTARY SWITCHES. Capable of up to 60 positions, Communicator Series switches have a unique rotor design that provides long-term contact registry and integrity. A single section accommodates 2 7-bar readouts or 2 8-bit binary codes with separate commas. Plastic materials have a 94-VO rating, and terminals are designed for pc-board mounting. $2.30 (1000) for single-section unit; $3.60 for double. **Oak Industries, Inc.,** Crystal Lake, IL 60014. Phone (815) 459-5000.
Circle No. 202

RESISTORS. The PW Series of ceramic-encased power wirewound resistors offers values from 0.001Ω to 30 kΩ in ratings from 2-50W. Designed primarily as low-cost alternatives to military-grade units, these units can also serve as fuse resistors that open circuit cleanly and permanently. In addition, the line includes noninductive windings and true pc styles with either radial wire leads or lugs. 7¢ to 19¢ (1000). **RCD Corp.,** 8 Blueberry Lane, Bedford, NH 03102. Phone (603) 669-0054. **Circle No. 203**

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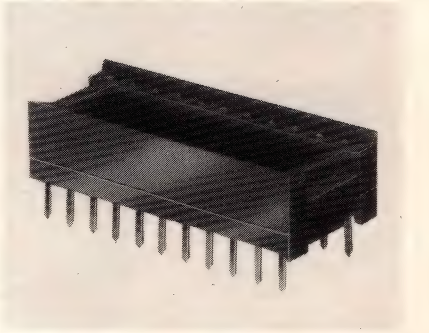
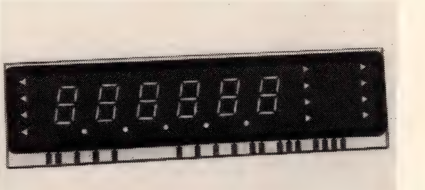
For more information, Circle No. 85

COMPONENTS/PACKAGING

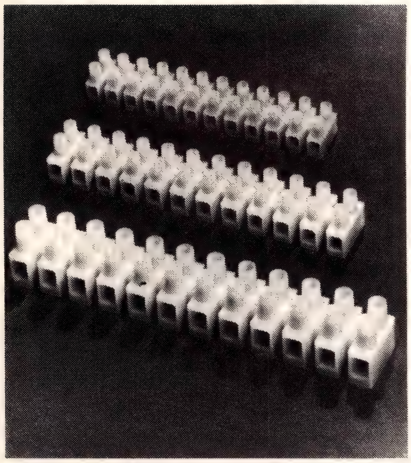


SOCKET. The bifurcated pin contacts in this 22-pin socket guarantee positive electrical contact with round or square pins. Precision molded with glass-filled thermoplastic, the socket's closed entry apertures prevent contact damage due to insertion of oversized pins. Solder wicking protection is provided, and a high standoff design eases board cleaning. Units come in either solder-tail or 2- or 3-level wire-wrap pin configurations. 78¢ to $1.79, depending on qty. **Aries Electronics, Inc.,** Box 231, Frenchtown, NJ 08825. Phone (201) 996-4096.
Circle No. 204

TRIMMERS. Cermet, immersion-sealed devices with 20 turns, Type MT trimmers have multifingered wipers for high adjustability and a TC of ±100 ppm/°C for high stability. The 3/8-in. square units are rated at 0.5W at 70°C, have a resistance range of 10Ω to 2 MΩ (±10%) and operate from −55 to +125°C. Three mounting styles, with both top and side adjust, are offered. $1.20 (500). **Allen-Bradley Co.,** 1201 S. Second St., Milwaukee, WI 53204. Phone (414) 671-2000. **Circle No. 205**



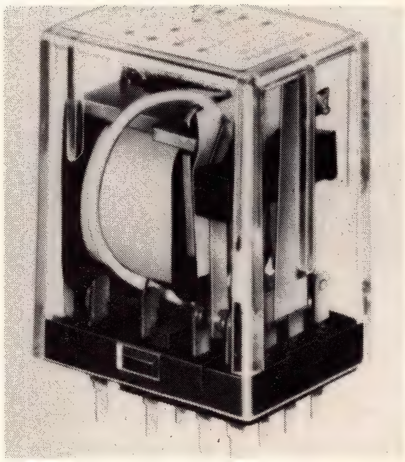
DISPLAY. A 6-digit, 7-segment device with 0.5-in. high characters, the W06-0002 gas-discharge display panel aims at the POS terminal market. Measuring only 5.2×1.4×0.25 in., this unit has 5 decimal points, plus 12 annunciator points that can be used to indicate the appropriate function. The display's "halo-effect" backlight yields improved visibility, clarity and contrast. $18.75. **Cherry Electrical Products Corp.,** 3600 Sunset Ave., Waukegan, IL 60085. Phone (312) 689-7702. **Circle No. 206**



TERMINAL STRIPS. Molded from natural polyamid 6.6 nylon, the EDS-Series strips have a flexible insulating body that can be field cut to any number of poles and shaped to any surface. Strips are available in terminals from 1 to 10 and in 12 poles; are rated for 300V; and can handle 16, 12 or 8 AWG wire. Their all-nickel-plated brass terminals are either deeply recessed or enclosed for dead-front safety. $6.80 to $194 (100). **Electrovert, Inc.,** 86 Hartford Ave., Mt. Vernon, NY 10553. Phone (914) 664-6090. **Circle No. 207**

POTS. Model 81/82 single-turn pots come with optional rotary-switch modules (Model 85/86) for applications that require an integral ON/OFF function. Any combination of up to 3 switches and/or resistance modules may be ganged behind the primary unit. Other features include dpdt or dpst contacts, CW or CCW detents, and in-line or right-angle solder lug terminals. Contacts (dpst) are rated for 2A at 125V rms. 89¢ (500) for a dpst rotary-switch module. **Bourns, Inc.,** 1200 Columbia Ave., Riverside, CA 92507. Phone (714) 781-5140. **Circle No. 208**

KEYBOARD SWITCH. With a 12° plunger, Model DI-120 is designed for stepped and sculptured keyboards. It has < a 0.5-in. profile and features a double set of cross-point, gold-alloy contacts, rugged construction and low contact bounce. Enclosing the contacts in a separate assembly within the switch housing prevents contamination. Life is spec'd at 20×10^6 operations, and terminals are sealed to permit soldering. 27¢ (100,000). **Data Interfaces, Inc.,** 12 Cambridge St., Burlington, MA 01803. Phone (617) 272-7456. **Circle No. 209**



RELAYS. Designed to provide high switching capacity, the HL Series offers spdt versions rated for 15A at 125V ac and dpdt models with 10A at 250V ac ratings. Coil voltages of 6 to 110V dc and 6 to 240V ac are standard on both. Max. switching power for dc and ac loads is 90W and 1.875 kVA, respectively. The relays have a mechanical life of $>10^8$ operations and are available in plug-in, pc-board and top-mounting configurations. $1.99 (1000). **Arrow-M Corp.,** 250 Sheffield St., Mountainside, NJ 07092. Phone (201) 232-4260. **Circle No. 210**

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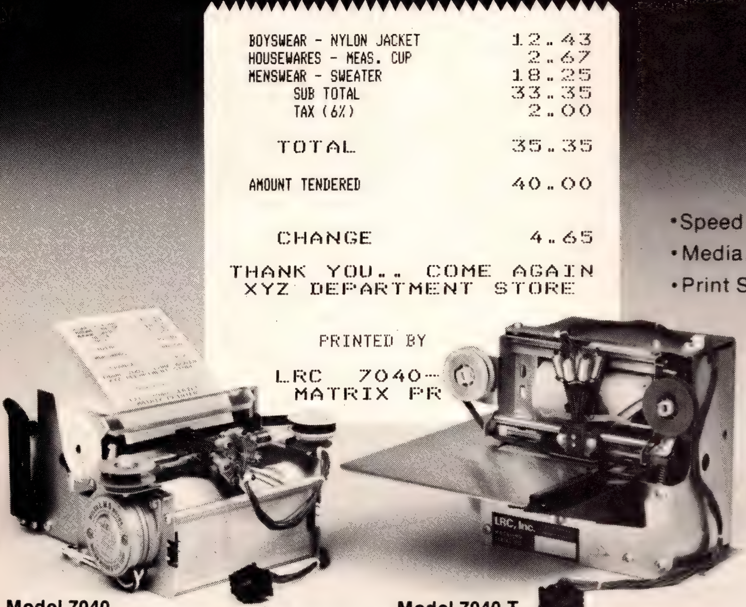

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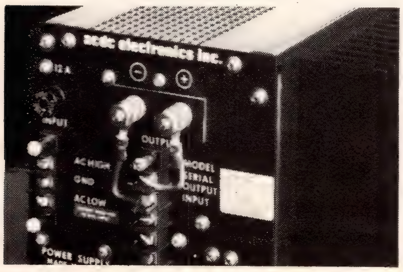
INSTRUMENTATION/POWER SOURCES

µP ANALYZER. The low-cost Model 50, essentially a sophisticated address and data-bus monitor with hardware breakpoint capability for microprocessors, is usable with all µP's that have accessible address and data buses up to 16-bit wide each. Model 50 can be used as a passive real-time monitor or as an interactive breakpoint generator, and operates to 4-MHz clock or instruction-cycle rates and to 8 machine cycles/instruction. $865. Delivery, 60 days ARO. **Systron-Donner Corp.,** 10 Systron Dr., Concord, CA 94518. Phone (415) 676-5000.

Circle No. 211

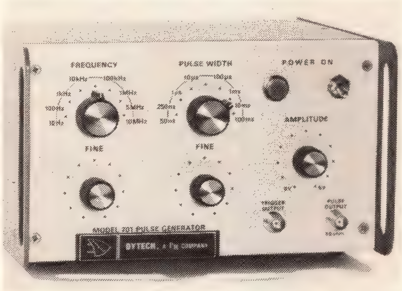
DMM. Model 283, with 4 ranges each for ac and dc voltage and current and 6 ranges for resistance, has a 3-1/2-digit, 0.41-in. LED display. Basic accuracy is 0.5% on dc V; 1% on ac V and Ω. Autodecimal, out-of-range indicator, auto polarity and 100% overrange are standard—as are a low-voltage circuit for Ω measurement and overload protection. $170. **Dynascan Corp.,** 6460 W. Cortland Ave., Chicago, IL 60635. Phone (312) 889-9087. **Circle No. 212**



SWITCHING SUPPLIES. Six 500W models, designed to meet UL478, have been added to the JP series. Rated at 2V/100A, 5V/100A, 6V/100A, 12V/43A, 15V/35A and 24V/23A, they operate from 90-132 or 180-264V, 48-63-Hz input. Their output is floating, and all offer inherent overload, overvoltage, reverse-voltage and thermal protection. Also, all units have provisions for remote sensing, remote shutdown, and remote control—and can be paralleled. $595. **ACDC Electronics,** 401 Jones Rd., Oceanside, CA 92054. Phone (714) 757-1880. **Circle No. 213**

ELECTRONIC THERMOMETER. Furnished complete with instructions, battery and 3 probes with 15-ft leads, the Model 1720 can monitor temperature anywhere—outdoors or in. Normal battery life is 1 yr. Probes may be placed as far as 1000 ft from the instrument simply by splicing an 18- to 20-gauge lamp cord into the probe lead. To operate, you simply switch to RUN, press a probe button and read. $69. **Pak-Tronics, Inc.,** 4044 N. Rockwell St., Chicago, IL 60618. Phone (312) 478-8585.

Circle No. 214



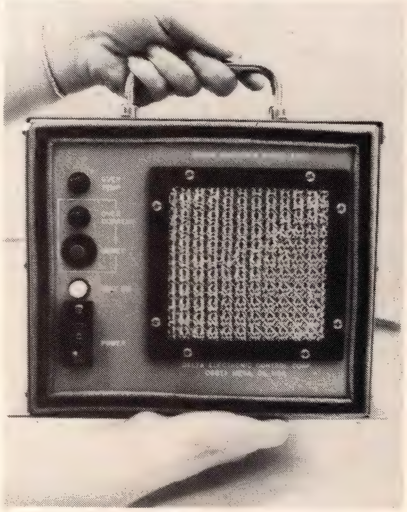
PULSE GENERATOR. Model 701 features a pulse repetition rate of 10 Hz to 10 MHz, an output pulse amplitude of 0-5V across 50Ω (0-10V unterminated), and rise and fall times of <5 nsec. Jitter, including pulse-width and rep.-rate, is <0.1%. A second (trigger) output of 1.2V has 50-nsec width and 10-nsec rise and fall time. $125. **Dytech Corp.,** 2725 Lafayette St., Santa Clara, CA 95050. Phone (408) 241-4333. **Circle No. 215**

COATING THICKNESS TESTER. The direct-reading Model ED reads out coating thickness in mils or microns on magnetic, nonmagnetic and nonmetallic base materials. Phase-sensitive circuitry and multicoil probe design permit stable operation and direct dial-in of the scale. Readings are nondestructive and can be made on as small a target as a 1/16-in. circle. Weight is 5 lb. and dimensions are 5×7×9 in. From $1195. **Sigma Labs, Inc.,** 88-11 31st Ave., Elmhurst, NY 11369. Phone (212) 898-2427. **Circle No. 216**

COUNTERS. The 3 communications counters of the 6240 Series share several features: 10-mV sensitivity, the ability to withstand exceptionally high input-signal levels, an RF input protected by overload fuse, full 8-digit LED display, selectable resolution in decade steps from 10 kHz to 0.1 Hz and a time-base oscillator offering ±2 parts in 10^6/yr. Bottom frequency for all 3 is 20 Hz. Model 6241A (100 MHz), $595; Model 6242A (512 MHz), $795; and Model 6243A (1250 MHz), $995. **Systron-Donner Corp.,** 10 Systron Dr., Concord, CA 94518. Phone (415) 676-5000.

Circle No. 217

POCKET-SIZE THERMOMETER. Especially useful for measuring small-area surface temperatures, the Model 33-100 contact thermometer with platinum sensor covers from −50 to +900°F or −50 to +500°C. Readings are within 0.1° over most of the range; accuracy at room temperature, 0.5% ±1 digit. Temperature changes are updated 3 times/sec on a LED readout. The thermometer operates for 4-1/2 hrs. on built-in, rechargeable nickel-cadmium batteries. **Barnes Engineering Co.,** 30 Commerce Rd., Stamford, CT 06904. Phone (203) 348-5381. **Circle No. 218**



CLASS D AMPLIFIER. Weight of only 52 lb. and size of 8-1/2×8-1/2×20 in. make the 5000W Model 61123 unique. The amp provides a 70-db dynamic range and handles peak power to 20 kVA for amplification of noise-type signals. IM distortion runs <0.5% and total harmonic distortion is <2%. Frequency response is flat to 10 kHz. Expected MTBF is >10,500 hrs., while power dissipation is <15% of the output VA. $8000. **Delta Electronic Control Corp.,** 1601 Pomona Ave., Costa Mesa, CA 92627. Phone (714) 646-7776. **Circle No. 219**

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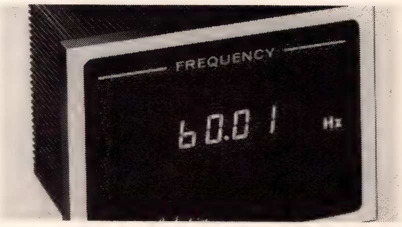
CHART RECORDER, Model DASH 1, runs 8 hrs./charge on Gel-cell batteries and has a chart drive mechanism that provides an infinite variety of chart speeds. It weighs 18 lbs. and features automatic chart-loading without threading. Specs include 0.5% F.S. accuracy and frequency response flat from dc to 100 Hz at 10-mm p-p amplitude. Sensitivity is 1 mV/mm to 1V/mm (50V F.S.). $1150. Delivery, 60 days ARO. **Astro-Med,** Atlan-Tol Industrial Park, West Warwick, RI 02893. Phone (401) 828-4000. **Circle No. 220**

POCKET DMM. Its 3000-count, 3-1/2-digit LED display, autopolarity and basic autozero—plus full overload protection—make the DM-50 unique. The measurement span is to 1000V ac and dc (1-mV resolution), to 2A ac and dc (1-µA resolution), and to 3 MΩ (1Ω resolution). Input Z is 10 MΩ. Complete with nickel-cadmium batteries and charger, $195. **Innovative Electronics Technology Labs., Inc.,** 335 Bear Hill Rd., Waltham, MA 02154. Phone (617) 890-5105. **Circle No. 221**

LOGIC TESTER. The field-portable Datatester 1200 weighs 11 lb and provides a single digital test capability to replace a separate oscilloscope, freq. meter, pulse timer, DMM, peak-reading VM and duty-cycle meter. Used in conjunction with systems signals, the Datatester 1200 can diagnose entire system logic arrays and isolate faults down to the component. The unit measures frequencies to 35 MHz and rise/fall times, widths and periods to 10-nsec resolution. $1995. Delivery, 60-75 days ARO. **Data Test Corp.,** 2450 Whitman Rd., Concord, CA 94518. Phone (415) 689-3583. **Circle No. 222**

SUPPLIES FOR µP'S keep the power supply external to the customer's product enclosure. The result is less heat and noise problems, less need for shielding and no need to obtain UL approval of the customer's product. All are designed for UL and CSA listing. Available models range from those that have a single output of 12V at 250 mA or 9V at 100 mA (M12-250 and M9-100) to the 3-output M5-1212 that delivers +5V at 500 mA, +12V at 150 mA and −12V at 150 mA. **Dynamic Instrument Corp.,** 933 L.I. Motor Parkway, Hauppauge, NY 11787. Phone (516) 234-2900. **Circle No. 223**

LAB/SYSTEM SUPPLY. The 200W Model 6002A supply operates both as a constant-voltage and constant-current source, with its output adjustable manually or (optionally) under HP-IB control. Adjustment range is 0 to 50V and 0 to 10A. Systems features include remote sensing, auto-series, auto-parallel and remote analog programming of voltage and current. Regulation specs at 0.01%; ripple and noise at 1 mV rms (10 mV p-p) over a 20-MHz bandwidth. $800, plus $350 for HP-IB option. **Hewlett-Packard Co.,** 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **Circle No. 224**



LINE-FREQ. MONITOR. Model LF60 measures frequencies from 10.00 to 99.99 Hz (1 to 300V input) with 0.01-Hz accuracy and a 1-sec update rate. The 4-digit, 0.4-in. LED readout is easily viewed, and a high-stability crystal reference eliminates the need for calibration. Input power is 110 or 220V ±20%. $275. **Electro Industries,** 109 Nassau Dr., Albertson, NY 11507. Phone (516) 621-6652. **Circle No. 225**

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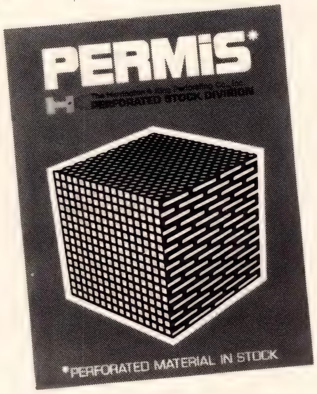

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SCIENTIFIC CALCULATOR with fractional capability, the 8-digit Model FX-19 can add, subtract, multiply and divide numbers expressed in fractions—as well as handle trigonometric and inverse trigonometric functions, common and natural functions, exponentiations, square root, reciprocals, sexagesimal/decimal conversion, π entry and statistical calculations including 2 kinds of standard deviations. Operation is on 4 penlight cells. $34.95. **Casio, Inc.,** 15 Gardner Rd., Fairfield, NJ 07006. Phone (201) 575-7400. **Circle No. 226**

THERMOMETER/MULTIMETER. In a pocket-sized probe, Model 12T packs a 3-1/2-digit, 14-range device that offers autoranging, autopolarity, and 0.1% accuracy (V dc). This unit measures from 1 mV to 750V dc, 200 mV to 750V ac, 1Ω to 19.99 MΩ, and −55 to 153.5°C. The price of $259 includes T/DMM probe body, voltage/resistance probe tip, temperature probe tip, ac battery charge/adapter, nickel-cadmium batteries, operator's manual and carrying case. **Logical Technical Services Corp.,** 71 W. 23rd St., New York, NY 10010. Phone (212) 741-8340. **Circle No. 227**

50W SWITCHER. Model TD101 measures only 6-1/2×4-1/2×1-1/2 in. and weighs just 1.7 lb. It operates from 90-130V, 47-450-Hz input, and features 75% efficiency (at full load), remote sensing, current limiting, inherent short-circuit protection, and a built-in crowbar that trips at 6V. Regulation is ±0.1%, line and load. Threaded inserts on the bottom and 1 side permit mounting to a chassis. $240. **Tele-Dynamics,** Div. of AMBAC Industries, Fort Washington, Pa 19034. Phone (215) 643-3900. **Circle No. 228**

LINEAR 1 kW RF AMP. Intended for use with SSB transmitters or transceivers in the 100W class, the 2-30-MHz Model T1000 amplifier is broadband and can operate on an infinite number of channels without tuning adjustment. Internal filters that provide harmonic attenuation of 60 dB can be selected by push-button or remote control. Four 250W amplifier modules are used, and the amplifier has both extensive metering and full protective circuitry. $2,795. **Trans World Communications, Inc.,** 1080 W. Washington Ave., Escondido, CA 92025. Phone (714) 747-1079. **Circle No. 229**

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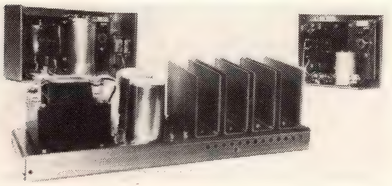
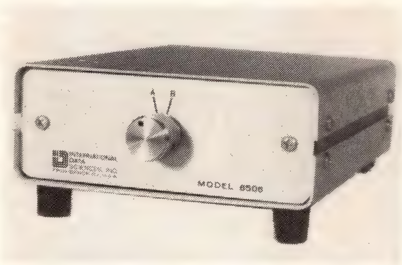
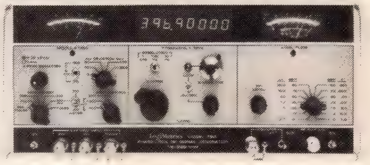


OPEN-FRAME SUPPLIES. Fifty-one models—including 35 single-, 8 dual- and 8 triple-output versions—comprise this OEM series. Voltages run from 5 to 24V in singles, from ±5 to ±15V in duals and ±12/5V or ±15V/5V in triples; and current outputs range from 1 to 50A. All feature ±0.15% regulation (line and load combined), 2-mV rms ripple and noise and built-in, short-circuit protection with automatic recovery. From $26. **Power Pac Inc.,** 18 Marshall St., South Norwalk, CT 06854. Phone (203) 866-4484. **Circle No. 230**

AUTORANGING DMM. A battery-powered 3-1/2-digit device, the Model PM2514 has LED readout, 10 MΩ input resistance, accuracies specified for 6 mo. and full overload protection. Ranges span 0.2 to 1000V dc and 0.2 to 600V ac (100-mV resolution) and 200Ω to 2 MΩ (with 0.1Ω resolution). The 2514 also can read temperatures from −60 to +212°C using an optional probe. $255. **Philips Test & Measuring Instruments, Inc.,** 400 Crossways Park Dr., Woodbury, NY 11797. Phone (516) 921-8880. **Circle No. 231**



EIA A,B SELECTOR SWITCH. Model 8506-D switches the 24-pin EIA RS232 or CCITT V.24 interface to either of 2 outputs. One modem may be switched to 1 of 2 front-end-processor data channels or to 1 of 2 data terminals. Alternatively, the module will switch a data channel from its on-line modem to a backup modem. Switch dimensions are 2-1/2×5-1/4×8 in., and highly reliable switching is provided by precious-metal, self-wiping contacts that are completely enclosed. $105. **International Data Sciences, Inc.,** 100 Nashua St., Providence, RI 02904. Phone (401) 274-5100. **Circle No. 232**



SIGNAL GENERATOR. With the Model 760 you get continuous, single-knob tuning from 1.5 to 520 MHz as well as tuning during phase lock, with 10-Hz resolution. Also featured are AM, FM and pulse modulation that can be used independently or simultaneously; an external frequency counter; and an internally detected RF output that tracks within 0.5 dB of the RF output, which is 1V, ±1/2 dB. $4675. Delivery, 120 days ARO. **LogiMetrics, Inc.,** 121-03 Dupont St., Plainview, NY 11803. Phone (516) 681-4700. **Circle No. 233**

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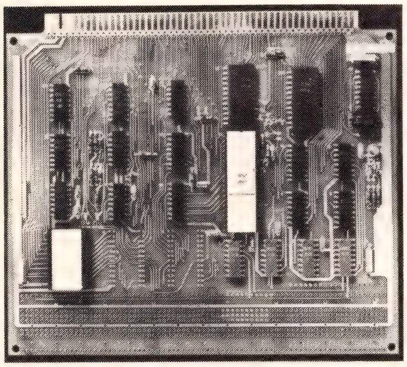
COMPUTERS/PERIPHERALS



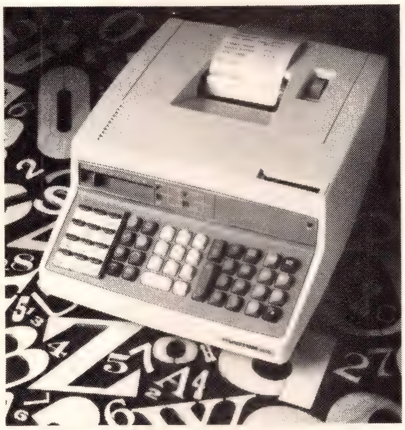
μP PROTOTYPE BOARD. The Adaptable Board Computer (ABC) comes complete with a Signetics 2650 μP, 1000 bytes of ROM containing PIPBUG (a loader, editor, debug program); 512 bytes of RAM, both serial and parallel I/O ports and a dual monostable onboard clock. By moving jumper wires, options such as asynchronous operation, external clock, and interrupt vector can be selected. $275; Kit, $190. **Signetics,** 811 E. Arques Ave., Sunnyvale, CA 94086. Phone (408) 739-7700 **Circle No. 234**

MICROCOMPUTER. Based on National Semiconductor's 16-bit PACE μP, the PACER allows users to address and enter data and commands with a 38-key calculator-type keyboard that outputs same to two 4-digit alphanumeric displays. A single keystroke defines characters; and systems functions such as examine or modify memory or registers, run, single-step, halt, breakpoints, etc., are also under keyboard/executive control. **Project Support Engineering,** 750 N. Mary St., Sunnyvale, CA 94086. Phone (408) 739-8550. **Circle No. 235**

VIDEO TERMINAL. The ADM-1A has a numeric pad with period, comma, plus and minus signs in concert with a 138 ASCII alpha-character upper- and lower-case keyboard. The 960-character display is arranged as 80 characters by 12 lines (optional 1920 characters in 24 lines). An assortment of 37 functional logic-board switches configures the unit for specific operating parameters. $1850. **Lear Siegler, Inc.,** 714 N. Brookhurst St., Anaheim, CA 92803. Phone (714) 774-1010. **Circle No. 236**

PROCESSOR SYSTEM, a desk-top unit with an Intel 8080 as the central intelligence unit, provides as standard 16k bytes of RAM and 2 floppy-disc drives with 2 communication channels. A CRT and printer are available options. Operation and programming utilize a CRT and/or printer on RS232 ports, which provide rates from 110 to 9600 baud. RAM and ROM memory is expandable to 64 bytes; up to 4k bytes of ROM are available and RAM is expandable in 16-byte increments. **Intelligent Computer Systems,** 777 Middlefield Rd., Suite 40, Mt. View, CA 94043. Phone (415) 961-8941. **Circle No. 237**

μC LEARNING SYSTEM. Based on the 8080A, the Mini-Micro Computer (MMD-1) makes learning μP's easier by including all necessary hardware, firmware and easy-to-understand instructions (the text is based on the famous Bugbook series). Data entry to the μC features a 16-switch keyboard organized for octal-code programming, and the system's 256 8-bit byte words of RAM are expandable to 512 words. Internal supplies provide +5 and ±12V. Weight is 7 lbs.; size, 10×12×3 in. Assembled, $500; kit, $350. **E & L Instruments Inc.,** 61 First St., Derby, CT 06418. Phone (203) 735-8774. **Circle No. 238**



CALCULATOR. Model 4900—a prompting, programmable desk-top calculator—asks questions and informs the operator of errors. This 14-digit calculator possesses full scientific functions and has 1792 max. program steps, a 5×7 dot-matrix (0.1-in.) character format and printing rate of 90-200 lpm. Each magnetic card holds 512 bytes. The printer uses a red/black ribbon and 3-7/16-in. × 175-ft. paper roll, and can print 4 copies. Weight is 25 lbs. $2,395. **Victor Comptometer Corp.,** 3900 N. Rockwell St., Chicago, IL 60618. Phone (312) 539-8200. **Circle No. 239**

DESKTOP CALCULATOR. The programmable 9830B, a more powerful version of the company's 9830A, comes with built-in string variables, matrix operation capability and 15,808 bytes of read/write memory that (for an additional $3,200) can be expanded to 30,144 bytes. Concurrently, the 9830A, now reduced to $4,900 (down 28%), can be modified to the equivalent of the new version. Both units feature a built-in tape cassette drive and BASIC. 9830B, $8,350. **Hewlett-Packard Co.,** 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **Circle No. 240**

PERIPHERAL CONTROLLER. Fully plug-compatible with Intel's SBC 80/10 and Intellec MDS, the KDP/C can simultaneously handle an ASCII-coded keyboard, a Victor Comptometer Corp. printer and an onboard 4-function calculator. Controlled by the μC system's 8080, the board gives users of these development systems instant keyboard input, hard copy and 4-function math peripheral capabilities. $295 (100). **Cybernetic Micro Systems,** 2460 Embarcadero Way, Palo Alto, CA 94303. Phone (415) 321-0410. **Circle No. 241**

TAPE TRANSPORT. The Bulk Data Storage unit (BDSU) is an environmentally sealed tape module capable of storing 16.8M bits using industry-standard block recording methods (or almost double that using high-density techniques). The transport has its 4-track head sealed inside the removable tape module, and features an electro-optical tape "ends-and-center" sensor and a bidirectional R/W of up to 30 ips. $5000 (OEM). **Electronic Memories & Magnetics,** 20630 Plummer St., Chatsworth, CA 91311. Phone (213) 998-9090. **Circle No. 242**

BAUD-RATE IC. A single baud–rate generator, COM 5026, provides any of 16 program or switch-selectable output frequencies. This chip offers 16 asynchronous/synchronous baud rates; direct UART/USRT compatability; a reprogrammable ROM for generating other frequencies; TTL and MOS compatability; on-chip input pullup resistors; accuracy to 0.01%; and a 50% duty cycle. Baud rate is externally selectable by a 4-bit address. The unit can be driven from a TTL-logic level input or by an external crystal. $11; $6 (100). **SMC Microsystems Corp.,** 35 Marcus Blvd., Hauppauge, NY 11787. Phone (516) 231-5151. **Circle No. 243**

COMPUTERS/PERIPHERALS

8080 EMULATOR. Designated the MAS-80, this in-circuit μP emulator connects to a user's system through a cable and plug that inserts into the 40-pin socket normally containing his 8080. Once "on-line" the system allows you to monitor and control your 8080 project from a full-service front control panel. Interesting bonuses include single-step, RAM debug and ADDMATCH (wait at address) features. $1195. **California Micro Computer,** 9323 Warbler Ave., Fountain Valley, CA 92708. Phone (714) 963-5050. **Circle No. 244**

PRINTER. Model 2424, a medium-speed line printer based on belt-mechanism technology, features a 132-col. print line and a 64-char. ASCII font. Ninety-six-char. ASCII and 64-char. EBCDIC fonts are optional. Print speed for the 64-char. version is 300 lpm; for the 96-char. version, 200 lpm; and for the 48-char. version, 400 lpm. The printer is housed in a floor-model cabinet (with optional "whisper-quiet" configuration available). **Data 100 Corp.,** 6110 Blue Circle Dr., Minnetonka, MN 55343. Phone (612) 941-6500. **Circle No. 245**

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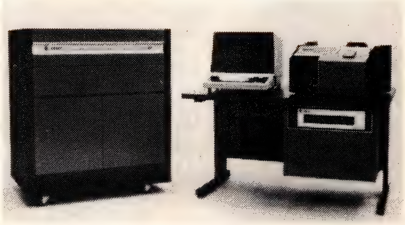
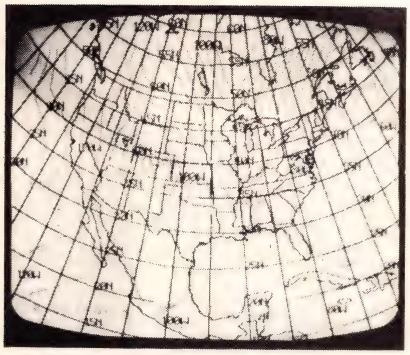


TERMINAL. Model UT-2, a programmable, remote batch terminal, includes a 12k-byte communications processor, card reader, synchronous adapter, cabinet, choice from 3 consoles and 3 line printers—plus software for operating the terminal in communication with customer-specified host computers. The UT-2 operates to 4800 bps with RS-232C-compatible modems. The desk-mounted card reader operates at 285 cpm. $700/mo. **Unitech, Inc.,** 1005 E. St. Elmo Rd., Austin, TX 78745. Phone (512) 444-0541. **Circle No. 246**

MICROPROGRAM CONTROLLER. The 57110 (MIL-$55)/67110 (COM-$25) consists of a μProgram sequencer capable of addressing 512-word pages of memory and has subroutine capability as well as a loop counter used for repeating loops of microcode. Suitable for use with conventional bit-slice μP's such as MM's 6701, AMD's 2901, the Intel 3002 and TI's 74S181 ALU arithmetic device, the controller comes in a 40-pin DIP and runs on 5V. **Monolithic Memories, Inc.,** 1165 E. Arques Ave., Sunnyvale, CA 94086. Phone (408) 739-3535. **Circle No. 247**

DATA TERMINAL. The Typing Power 55^{TM} terminal is a letter-quality work station for use with any host computer. Featuring a universal interface and utilizing USASCII, BCD, and EDBIC code sets, the terminal uses standard paper or forms of any size up to 15 in. wide, prints 132 columns at 10 characters/in. and 158 columns at 12 characters/in. $9000. **Qualterm Terminals,** 2007 O'Toole Ave., San Jose, CA 95131. Phone (408) 263-7800. **Circle No. 248**

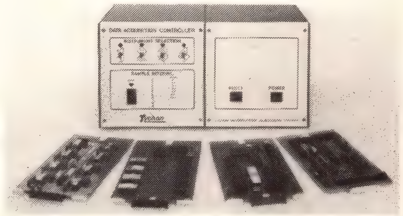


GRAPHICS DISPLAY. Series GCT-3000, a fully programmable system, combines high-speed display data processing and fast-access MOS RAM refresh memories with the ability to perform automatic block transfers using DMA. The heart of the system, the GCT-3011 Programmable Graphic Processor, provides 47 mnemonic instructions specifically graphics-manipulation oriented. **Genisco Computers,** 17805-D Sky Park Circle Dr., Irvine, CA 92714. Phone (714) 556-4916. **Circle No. 249**

REMOTE TERMINAL. The DATACORDER packs a self-contained intelligent terminal utilizing a µP with 8k of RAM storage (expandable to 12k) into a unit the size of an electric typewriter. Data enters through a full alphanumeric keyboard with calculator pad, while prompting messages and keyed input are displayed on a 32-character electronic readout. The unit is programmed via tape cassette. $3970 to $5875. **IESI,** 408 N.E. 72nd St., Seattle, WA 98115. Phone (206) 525-6800. **Circle No. 250**

DATA SET. The McModem is a private-line data set that operates on local distribution lines at speeds from 1200 to 19,200 bps. The modulation scheme used meets Bell Technical Pub. 43401 at all speeds. Operatable on either a 2- or 4-wire facility, the data set is available with RS-232, CCITT V. 24, MIL 188C, or 20-mA loop interface. $995. **Data Control Systems,** Box 584, Danbury, CT 06810. Phone (203) 743-9241. **Circle No. 251**

CARTRIDGE TRANSPORT. Designed for the 3M Co.'s DC100A Data Cartridge, the MICRO-DRIVE Model 101 offers R/W speed of 25 ips, rewind/search of 75 ips, and recording density of 1600 characters/in. The drive requires only a single 15V dc supply, draws 700 mA (avg.) and transfers data at 20k bits/sec. The cartridge stores up to 1,340,000 bits. $470 (100). **Instrumentation Technology Corp.,** 18333 Eddy St., Northridge, CA 91325. Phone (213) 886-2034. **Circle No. 252**



DAS CONTROLLER. Containing both analog and digital I/O, the µP-based Data Acquisition Controller inputs information for local control, or for storage and serial transmission to remote locations. Digital inputs can be used for set points, control, clocks, terminals, and alarms while A-D I/O can control sequencing, timing and sensing, and output to recorders, meters and servos. $2500. 60-90 days ARO. **Tychon, Inc.,** Box 242, Blacksburg, VA 24060. Phone (703) 951-9030. **Circle No. 253**

Consumer Tested Remedy for Sick Car Performance Sparks New Life in Pre-1975 Cars.

Owners of pre-1975 cars get better performance with less maintenance when they install one of the Mark Ten C.D. Electronic Ignition Systems. In fact, thousands of users testify the Mark Ten has noticeably improved their automobile's performance. As a California doctor stated after using the Mark Ten for 95,000 miles. "...I can 'feel' the difference in performance between my conventional ignition and the Mark Ten..."

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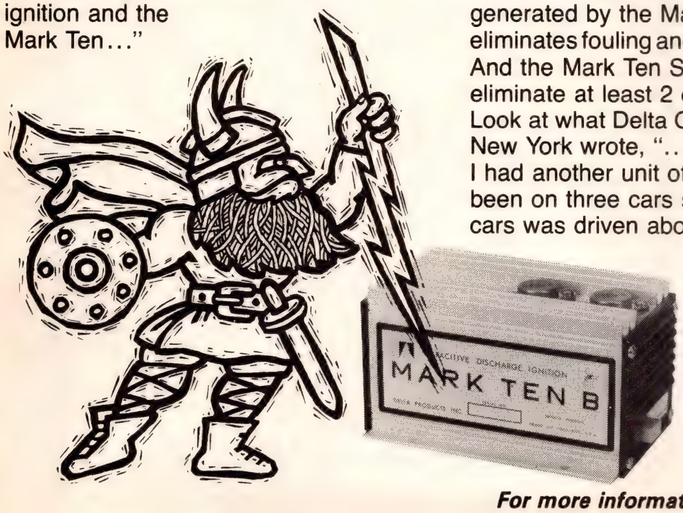


FLOPPY-DISC TERMINAL. The RDS/FSDR is a 2-way batch terminal with complete editing and data-search capability, 311k bits of flexible disc storage and full RS-232 compatibility. The unit can access over 2400 addressable lines of 128 characters within 0.3 sec, or can accept I/O from any asynchronous CRT or keyboard/printer terminal. $1995 and up. Delivery, 60 days ARO. **Randal Data Systems Inc.,** 365 Maple Ave., Torrance, CA 90503. Phone (213) 320-8550.

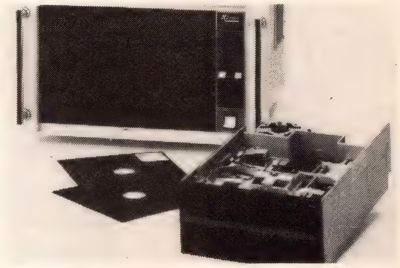
Circle No. 254

DOT-MATRIX PRINTERS. Capable of printing 165 and 330 USASCII characters/sec, the single-head 5701 ($1900) and double-head 5703 ($2400) respectively output 75 and 50 lpm at 132 characters/line. The units output <65 dB of noise, and feature human-engineered design. Four 2×132-bit shift registers make up the printer's buffer memory. **Juki Machinery Corp. of America,** 3186-G Airway Ave., Costa Mesa, CA 92626. Phone (714) 540-4533. **Circle No. 255**

CACHE BUFFER. Cache/45™, said to be the first 2048-byte cache buffer available for use with the PDP 11/45, is contained on a single board and has twice the capacity of present buffers. Depending upon software used, this unit can increase processing speeds by 100%. $7,000 in unit qty., with delivery 30 days ARO. **Able Computer Technology,** 1538-E E. Chestnut St., Santa Ana, CA 92705. Phone (714) 547-6236.

Circle No. 256

I/O BUS CONVERTER. The RTP7410/65 (a single-board unit) allows the company's complete RTP family of measurement/control equipment to operate under computer control. Up to 8 RTP controllers can be connected to one 7410/65 in daisy-chain fashion. $300; delivery, 45 days. **Computer Products, Inc.,** 1400 N.W. 70th St., Box 23849, Ft. Lauderdale, FL 33307. Phone (305) 974-5500. **Circle No. 257**



FLOPPY-DISC SYSTEM. The RFS 7500 system incorporates from 1 to 4 flexible disc drives, formatter electronics and power supply into a single 19-in. rack-mountable chassis. µP-based, the formatter performs many functions within the system that normally require computer time in other makes. The user can select IBM format, or can program a 1- through 32-sector format using a pc-mounted DIP switch. <$2400 in OEM qty. (dual drive). Delivery, 90 days ARO. **Remex,** 1733 Alton St., Santa Ana, CA 92705. Phone (714) 557-6860.

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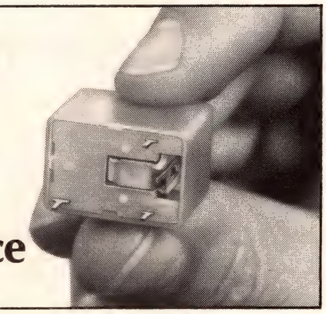

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Mounts on .69" centers...
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The relay has a 450 mW pick-up sensitivity (180 mW available). Contact rating is 3A res @ 28V dc. 120V ac. Contact resistance is 0.10 ohm.

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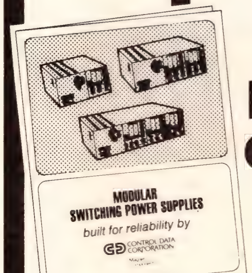
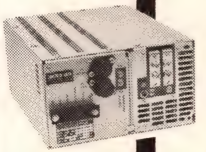
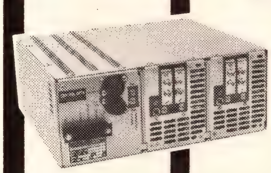


OEM DESIGNERS Get this FREE Design File on CDC's new modular switching power supplies





These compact, modular power supply switchers simplify design in 300-600 watt applications and keep costs down too. (They're priced at less than 90¢ per watt!) Benefits to the end user include **low EMI noise levels** (we are designed to meet VDE STD 0875) and **highly reliable operation** plus convenient maintenance and easy add-on capability up to 1200 watts in a single, 19 in. rack. Get specs, prices and feature details today from:

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CONTROL DATA CORPORATION
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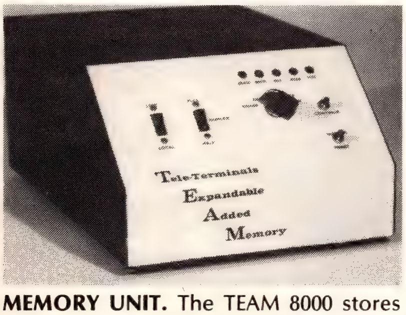
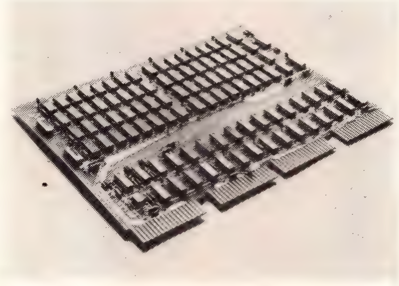
For more information, Circle No. 95

DATA SET. The GDC 9601 solid-state LSI data set features 9600-, 7200- and 4800-bps operation; RS232C and CCITT-V24 interfaces; and operation over basic 3002 lines. Its advantages include: constant monitoring provided by data lamp; marginal circuit and line signal detection indicators; both local and remote testing; and voice capability for communication with remote operator. $7,250; delivery, 30 days. **General DataComm Industries, Inc.,** 131 Danbury Rd., Wilton, CT 06897. Phone (203) 762-0711. **Circle No. 259**

MILITARIZED PRINTER. The Model T-1148 combines a fully militarized pin-matrix impact ASR teleprinter, µP electronics and an internal 16,000-character memory into 1 compact, modularly constructed unit. Providing full message composition and editing capability, the printer offers ASCII, BAUDOT or other code sets and prints at 120 characters/min. A built-in test feature allows mean-time repairs of 15 min. **Electronic Communications, Inc.,** Box 12248, St. Petersburg, FL 33733. Phone (813) 381-2000. **Circle No. 260**



MEMORY UNIT. The TEAM 8000 stores 8000 characters from either a terminal keyboard or data received from a remote source, replacing paper or mag tape for data transmission. This unit has an EIA RS232C I/O connection for interface to any CRT, printer or other peripheral device. Memory is fully editable. $1495. **Tele-Terminals, Inc.,** 6325 Welcome Ave. North, Brooklyn Park, MN 55429. Phone (612) 535-5330. **Circle No. 261**

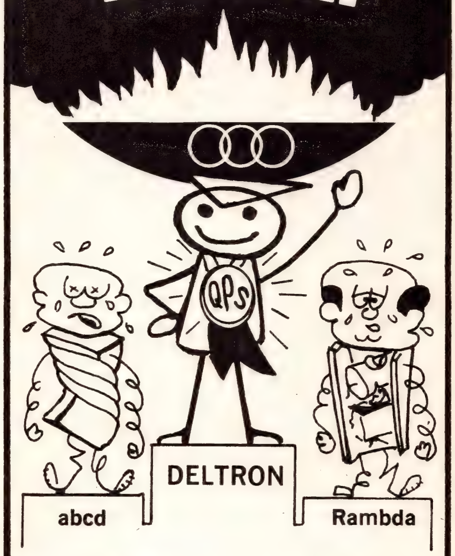


DYNAMIC MEMORIES. The Mastermind™ Series add-in dynamic memory modules are designed specifically for complete compatability with the LSI-11. Mastermind 2000-8 and 2000-16 offer 8192 and 16,384 words of 16 bits each, respectively. Both are directly pluggable memories, rated at 500-nsec access time and 800-nsec cycle time. Power required is 12V at 0.5A and 5V at 2A. Model 2000-8 (8k), $875; 2000-16 (16k), $1450. Delivery, 4 wks. ARO. **Memory Systems, Inc.,** 3341 W. El Segundo Blvd., Hawthorne, CA 90250. Phone (213) 772-4220.
Circle No. 262

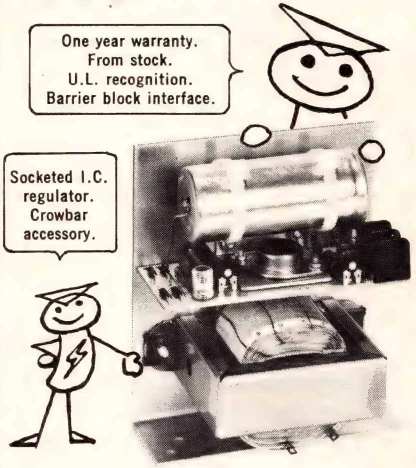
PAPER-TAPE TRANSMITTER. Model 1200 is a self-contained, punched-tape reader/transmitter with integral power supply and dual-output (modem & terminal) RS232C serial interface. This unit links directly to intelligent terminals, CRT displays, printers and data terminals. Parameters include switch-selectable transmission rates of 110, 150, 300, 600 and 1200 baud, parity selection and half or full duplex. $895. **BAI Data Products Div.,** Box 681, Cherry Hill, NJ 08003. Phone (609) 663-1191.
Circle No. 263

GRAPHICS JOYSTICKS. Both the JOY-A and JOY-B allow the operator to quickly and accurately position a cursor on a CRT. JOY-B incorporates a user-controlled switch at the end of the stick to provide status information; the user simply presses this switch when the cursor is positioned at the desired location. These units provide minicomputer interrupts at a 100-Hz rate and interface with NOVA, ECLIPSE or PDP-11 computers. **Megatek Corp.,** 1055 Shafter St., San Diego, CA 92106. Phone (714) 224-2721. **Circle No. 264**

ANOTHER WINNER



QPS series Power Supplies $21.50



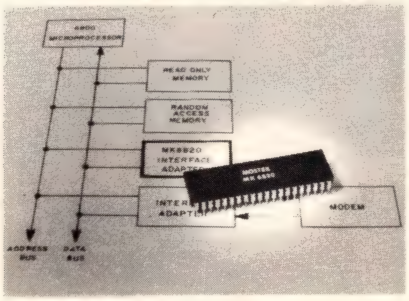
MODEL	QPS-1	QPS-2	QPS-3
RATINGS Volts/Amps	5/3 or 6/2.5	12/1.5 or 15/1.2	24/1
QTY.	1	100	250
PRICE	$24.00	$22.50	$21.50

Deltron inc.

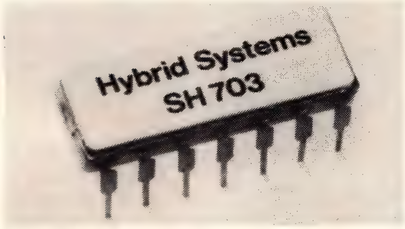
Wissahickon Avenue
North Wales, PA 19454
Tel: 215/699-9261 Twx: 510/661-8061
AC-10

For more information, Circle No. 96

IC'S/SEMICONDUCTORS



μP INTERFACE. Peripheral Interface Adapter MK 6820 interfaces peripheral equipment with the 6800 and is an improved-performance, pin-for-pin replacement for the AMI 6820. The circuit is also a generalized I/O for any μP bus. The 40-pin DIP comes in either a 300-mW max./250-mW typ. or 400-mW max./300-mW typ. version and provides 2-MHz/1-MHz bus operation, is completely static and requires a single 5V supply. 6820N-1, $5.50 (100). **Mostek Corp.,** 1215 W. Crosby Rd., Carrollton, TX 75006. Phone (214) 242-0444. **Circle No. 265**

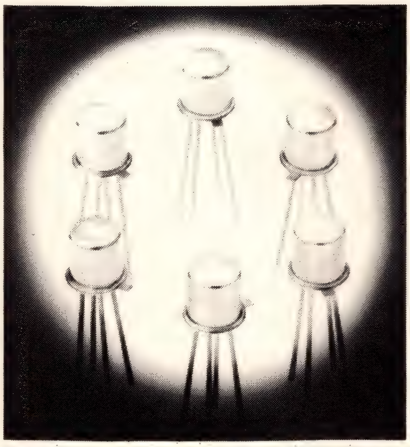


SAMPLE AND HOLD. Model SH 703 meets speed and accuracy requirements of most 12-bit data-acquisition systems. Specs include: acquisition time, 4 μsec; settling time, 4 μsec; droop rate, 50 mV/sec max.; aperture time, 50 nsec; and aperture uncertainty, 5 nsec. Signal range is ±10V. The units (housed in 14-pin DIP's) can be either inverting or noninverting; screening is either per MIL-STD 883, level B or commercial. $22. **Hybrid Systems Corp.,** Crosby Dr., Bedford, MA 01730. Phone (617) 275-1570. **Circle No. 266**

I^{2}L LOGIC. This semi-custom LSI logic permits 4-wk delivery of first prototypes for as low as $1800. Said to be a major price breakthrough, SWAP is based on a master chip, with two noninterconnected versions available: a 16-pin chip with 208 gates and 14 interfaces; and a 24-pin unit with 408 gates and 22 interfaces. To implement a circuit, a SWAP Custom Design Kit ($25) is needed. The kit includes a manual, work sheets and 15 sample devices. **Stewart-Warner Microcircuits,** 730 E. Evelyn Ave., Sunnyvale, CA 94086. Phone (408) 245-9200. **Circle No. 267**

TACHOMETER speed switch, Series IM 2907/2917, consists of a F/V converter with a high-gain op amp/comparator—which operates a load whenever the input frequency reaches a selectable rate. The output swings to ground for zero-frequency input. Comparator output is floating transistor, allowing either a supply or ground-referenced load of up to 50 mA. Collector voltage may be above supply voltage to a V_{CE} of 28V. $1.65 (100). **National Semiconductor Corp.,** 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone (408) 732-5000. **Circle No. 268**

RAM'S. Organized 256×4, 3 RAM's are suited for 4-, 6- or 16-bit μP's. Each type comes in 3 speed ranges: 1000-, 650- and 450-nsec max. access and R/W cycle times. All memories operate from a single +5V supply and are fully TTL compatible; typ. dissipation equals 175 mW. These devices have fully decoded direct addressing and are housed in plastic or ceramic DIP's. The TMS 4039/2101 comes with 22 pins; 4042/2111, with 18 pins; 4043/2112 with 16 pins. Plastic DIP prices: 1000-nsec access time, $3; 650 nsec, $3.25; 450 nsec, $3.80 (100). **Texas Instruments, Inc.,** P.O. Box 5012, Dallas, TX 75222. Phone (214) 238-2011. **Circle No. 269**



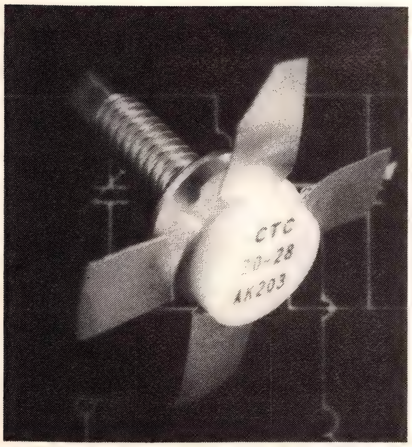
OCI'S. Series 3N243/244/245 optically coupled isolators are designed for pulse-transformer and mechanical-relay replacement. Guaranteed min. current transfer ratios are 15% for the 3N243, 30% for the 3N244, and 60% for the 3N245. All devices feature 1-kV isolation and will withstand HTRB at 125°C and a V_{CE} of 20V. The optoisolators come in a hermetically-sealed TO-18 package. 3N243, $3.35; 3N244, $4.31; 3N245, $5.83 (1000). **Optron, Inc.,** 1201 Tappan Circle, Carrollton, TX 75006. Phone (214) 242-6571. **Circle No. 270**

MULTIPLEXERS. The MM54C150/MM74C150 and MM72C19/MM82C19 multiplex 16 digital lines to 1 output. Data is inverted from input to output. Both the MM74C150 and Tri-State^R MM82C19 feature clamp diodes on all inputs, guaranteed noise margin of 1.0V, noise immunity of $0.45V_{CC}$ (typ.), and supply range of 3-15V. Both devices are available in either a 24-pin DIP or 24-lead package. MM74C150 (Epoxy B), $3.80 (100). **National Semiconductor Corp.,** 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone (408) 732-5000. **Circle No. 271**

LED'S. The 3-lead 232RG contains both red and green LED dies in the same capsule. If desired, both dies can be energized simultaneously, providing a trichromatic capability with red and green combining to emit yellow. Typ. luminous intensity at 10-mA (red) and 20-mA (green) forward current is 1.5 mcd. Applications include built-in diagnostics/fault locators, visual indicators and large display components. 97¢ (1000). **Industrial Electronic Engineers, Inc.,** 7740 Lemona Ave., Van Nuys, CA 91405. Phone (213) 787-0311. **Circle No. 272**

PHOTODIODES. Silicon avalanche photodiodes C30817/84/95, supplied in low-profile TO-5 packages, have a useful photosensitive area of 0.5 mm^2. The C30872, with 7 mm^2 area, comes in a low-profile TO-8 package. The 400-1100 mm C30817/72 are general-purpose and have typ. rise and fall times of 2 nsec. C30884, also 400-1100 mm, has modulation capability to 400 MHz and typ. rise and fall times of 1 nsec. C30817, $159; C30872, $475. Delivery, 60 days ARO. **RCA/Solid State Division,** Route 202, Somerville, NJ 08876. Phone (201) 685-6423. **Circle No. 273**

FREQUENCY PRESCALERS. Five UHF-programmable dividers, designed as prescalers for frequency synthesizers, feature toggle frequencies to 500 MHz and provide increased loop response and better channel spacing. All units can be logically programmed to divide by either of 2 ratios. They are available with either ac- or dc-coupled inputs and all I/O's are ECL compatible. Specs for the ac-coupled SP8740 include ratios of ÷5/6 and toggle rates of 0 to 300 MHz. $11.50 (100). **Plessey Semiconductors,** 1674 McGaw Ave., Irvine, CA 92714. Phone (714) 540-9945. **Circle No. 274**



BIAS CIRCUIT. The Z0-28 is said to offer a unique combination of low-impedance bias source and high current capability. The unit is designed for linear amplifiers that offer extremely high output power, while utilizing relatively low-β RF power transistors. Operation is from any voltage to 28V. Housed in an RF power-transistor package, the circuit can be mounted to the same heat sink as the RF transistor, permitting good thermal tracking. $14.40 (100). **Communications Transistor Corp.,** 301 Industrial Way, San Carlos, CA 94070. Phone (415) 592-9390.
Circle No. 275

TRANSISTOR. Said to be the highest power 28V single-sideband RF power transistor available, the S175-28 offers output power of 175W, good linearity and a high safe-operating area. It is well-suited for use as an output stage in a high-power linear amplifier. Guaranteed specs include intermodulation distortion of −32 dB at full power, and min. gain of 14 dB. The device is 100% tested for infinite VSWR at all phase angles at full CW output power. $55 (100-499). **Communications Transistor Corp.,** 301 Industrial Way, San Carlos, CA 94070. Phone (415) 592-9390.
Circle No. 276

DIODES. Typ. Q values of the DKV-6520/30 series of hyperabrupt tuning diodes have increased to twice the previous values. Guaranteed min. Q's have also increased 150-190%. Series DKV-6520 (HF/VHF) offers C_{T4} capacitances of 20-200 pF, with typ. Q's of 420-125. Series DKV 6530 (UHF) offers C_{T3} capacitances of 11.5-28 pF, with typ. Q's of 700-400. Tuning ratios equal 5:1 from 4 to 20V. **Alpha Industries, Inc.,** 20 Sylvan Rd., Woburn, MA 01801. Phone (617) 935-1236.
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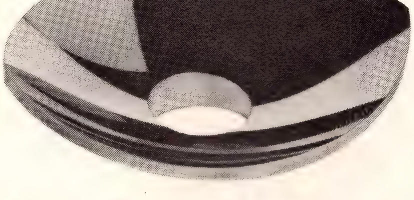

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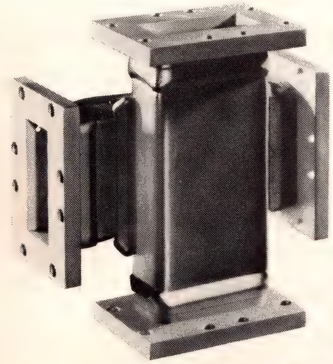

GAR
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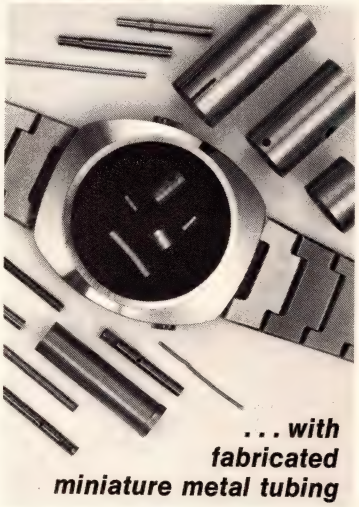
REDUCE ELECTRONIC COMPONENT COSTS



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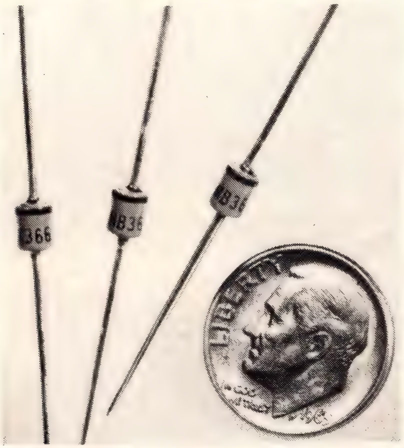


RECTIFIERS. A line of high-speed switching 2 and 3A silicon rectifiers combines miniature size with high surge capability, low thermal resistance and rugged mechanical design. Metallurgically bonded and voidless-packaged, they feature a hermetic seal, hard-glass case and opaque-painted body insensitive to ambient light. All are designed for high reliability, and meet or exceed the requirements of MIL-S-19500. $5.45 (100). **Microsemiconductor Corp.,** 2830 S. Fairview St., Santa Ana, CA 92704. Phone (714) 979-8220.

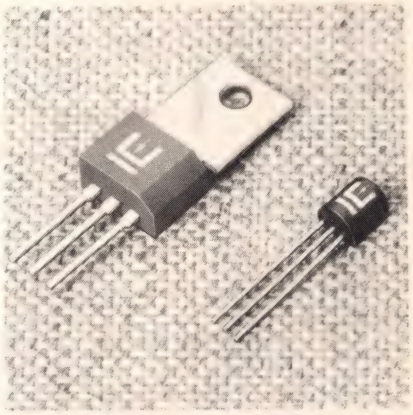
Circle No. 278

AMPLIFIER. The TDA 1037—a voice-frequency power amplifier with 5W output power at 14V and 4Ω load resistance—is designed for the entertainment field. Operating voltage starts at 4V, and input sensitivity reaches 150 mV at full load. Thermal resistance is 12° K/W. Internal sensor transistors and an external cooling tab help dissipate heat. The unit, housed in a 9-pin SIL package, is protected against thermal overloading. **Siemens Corp.,** 186 Wood Ave., South Isalin, NJ 08830. Phone (201) 494-1000.

Circle No. 279

ZENERS. The LM129 and LM329 family are precision, multicurrent temperature-compensated 6.9V zener references with dynamic impedances a factor of 10 to 100 less than discrete diodes. Active circuitry buffers the internal zener of the LM129, allowing operation over a 0.5 to 15-mA range with little change in performance. The LM129 is housed in a TO-46; the LM329, in either a hermetic TO-46 or a TO-92. LM129AH (0.001%/°C, −55 to 125°C), $15 (100). **National Semiconductor Corp.,** 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone (408) 732-5000.

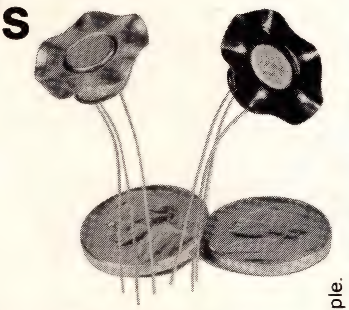
Circle No. 280



DARLINGTONS. A line of 4 power Darlingtons (U2TA/B/DG) in TO-202 plastic packages is said to include the only available 5A, 300V fast-switching unit. The other devices have I_C's of 3, 5 and 10A and BV_{CEO} of 60-100V dc. All have integral bias resistance and protective diode, and feature both high current gain and saturation voltages as low as 1.5V max. The 3A, 100V device in a TO-92 is claimed a first for pulse-power applications where high-power packages are not needed. 40¢ - $1 (1000). **Unitrode Corp.,** 580 Pleasant St., Watertown, MA 02172. Phone (617) 926-0404.

Circle No. 281

New Press Top Coolers are today's best buy for a nickel.



Here's how to really cut cooling costs for TO-5 packages. Wakefield's new 298 Press Top Coolers cost only 5¢ each in 5,000 quantity. This is less than ½ the price of comparable IERC Fan Tops or Thermalloy devices . . . and at no sacrifice in performance. With $\Delta T_{C\text{-}A}$ less than 70°C/W.

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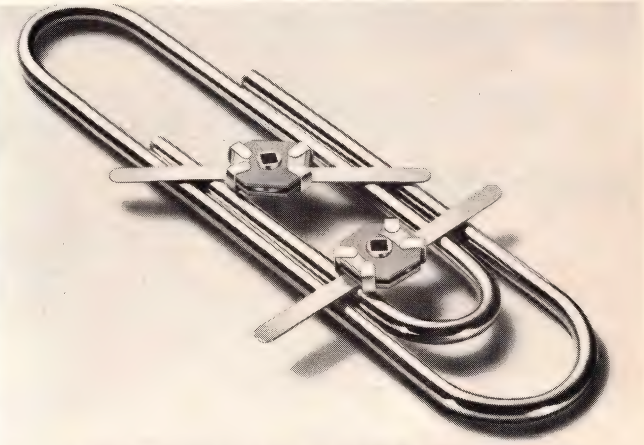

THIN-TRIM CAPACITORS FOR HYBRIDS AND MIC'S

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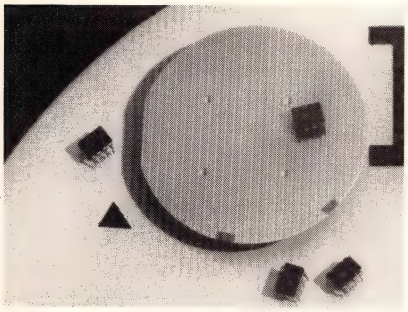
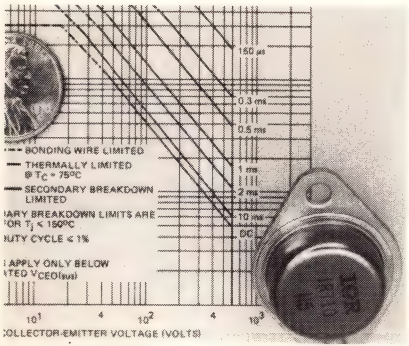


CLOCK. Performing the functions of 4.19-MHz oscillator, frequency divider and output driver for synchronous motors, the ICM7038 is a CMOS clock circuit that operates from 1.5V. The 8-pin DIP is designed for quartz-clock and timer applications using oscillator frequencies between 2 and 10 MHz. Current drive is 1 mA (min.); power dissipation, 105 μW (at 1.5V). DIP, $3.15; dice, $2.52 (100). **Intersil, Inc.,** 10900 N. Tantau Ave., Cupertino, CA 95014. Phone (408) 996-5000. **Circle No. 282**

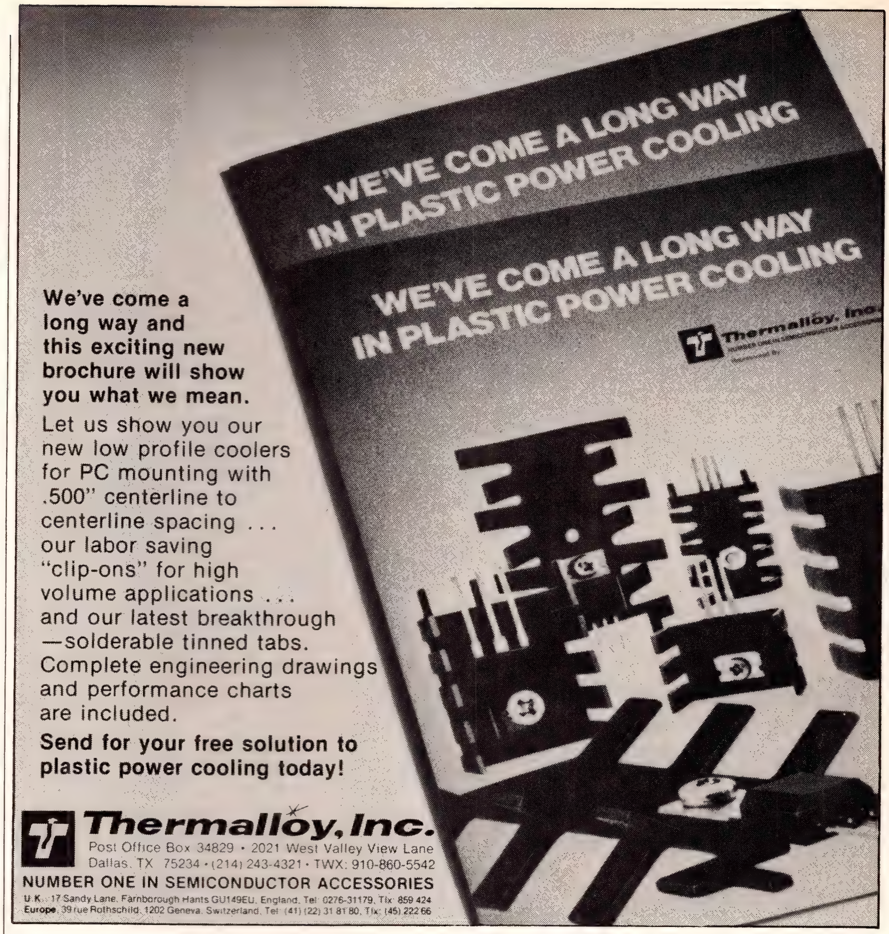


TRANSISTORS. A series of npn power transistors carries ratings to 50W and 900V. The IR701 and IR710 are well-suited for use in linear regulators, power amplifiers and vertical-output circuits. IR701 offers a continuous collector current rating of 1A and collector-base voltage of 800V; IR710 is rated for 3A and 900V. IR701, $2.69; IR710, $2.39 (100). **International Rectifier,** Semiconductor Div., 233 Kansas St., El Segundo, CA 90245. Phone (213) 678-6281.

Circle No. 283

REGISTER. The 8-bit Am25LS22—a serial/parallel register available in a molded or hermetic DIP—comes with a sign-extend function for use with the Am25LS14 multiplier. The 25LS22 completes a 3-part circuit set, including the 25LS15 (a quad, serial adder/subtractor), designed for filtering and signal-processing applicatons up to 30 MHz. Molded DIP, $4.60 (100). **Advanced Micro Devices Inc.,** 901 Thompson Pl., Sunnyvale, CA 94086. Phone (408) 732-2400.

Circle No. 284



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923332	208 (assem.)	872	8 (16's)	8	2	4-9/16x5-9/16	28.95
923334	201-K (kit)	1032	12 (14's)	2	2	4-9/16x7	24.95
923331	212 (assem.)	1224	12 (14's)	8	2	4-9/16x7	34.95
923326	218 (assem.)	1760	18 (14's)	10	2	6-1/2x7-1/8	46.95
923325	227 (assem.)	2712	27 (14's)	28	4	8x9-1/4	59.95
923324	236 (assem.)	3648	36 (14's)	36	4	10-1/4x9-1/4	79.95

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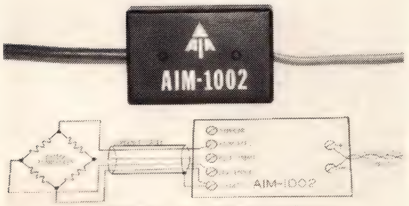
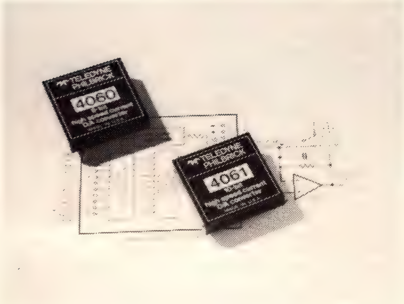
MODULES/SUBASSEMBLIES



Connections for bridge transducers

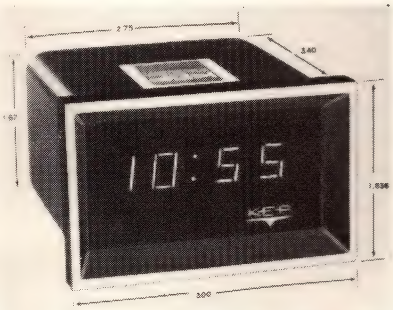
BRIDGE TRANSDUCER DIGITIZER also transmits remote-location output data over the single-wire pair that provides power and reference voltage. Available in 8 different input ranges from 10 mV to 10V F.S., the AIM-1002 responds with a pulse frequency output (100 kHz F.S.) to an accuracy of ±0.02%. Specs include gain TC of ±20 ppm/°C max. and offset TC of ±10 μV/°C max. $145. **Automated Industrial Measurements Inc.,** Box 125, Wayland, MA 01778. Phone (617) 653-8602. **Circle No. 166**

VIDEO/ANALOG CONVERTER. Model 6280 can easily convert a single-input composite video signal into 3 separate analog outputs of video alone (0-10V), vertical ramp and horizontal ramp (both ±10V). Featuring a bandwidth of 1 Hz to 5 MHz, this module allows standard composite video to be monitored on conventional XY analog displays and can also implement a video/microprocessor interface. $265. **Optical Electronics, Inc.,** Box 11140, Tucson, AZ 85734. Phone (602) 624-8358. **Circle No. 167**

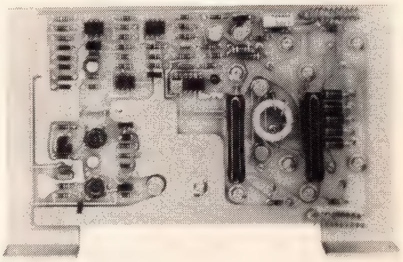


D/A. Featuring a guaranteed settling time of 85 nsec, Models 4060 (8 bits, $119) and 4061 (10 bits, $139) are internally trimmed for an offset of <±1/4 LSB over the 0 to 70°C operating range. Each has an internal precision reference for adjustment-free operation. Inputs are TTL/DTL compatible, and both units offer unipolar and bipolar outputs of 0-10 mA and ±5 mA. **Teledyne Philbrick,** Allied Dr. at Rt. 128, Dedham, MA 02026. Phone (617) 329-1600. **Circle No. 168**

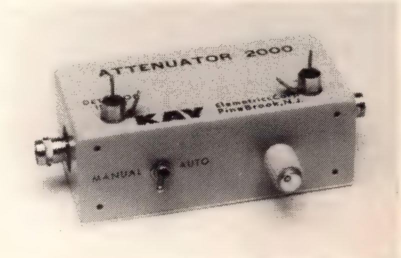
DC/DC CONVERTER. Covering an output range of 500V (5 mA) to 2000V dc (1.5 mA) from 12, 24 or 28V dc input voltages, the 24 models of the HR series allow 20% external voltage trim on pc pins. Fully encapsulated, these nonisolated units offer line regulation of 0.1% as well as 0.3% regulation from zero to full load, and insure output voltage ripple of less than 0.2% p-p. $164. **Wall Industries, Inc.,** 175 Middlesex Tpk., Bedford, MA 01730. Phone (617) 275-0708. **Circle No. 169**



COUNTER. Combining small size with an attractive front panel, Model 124 operates up to speeds of 300 kHz, yet boasts immunity to random noise and vibration. When the 4-digit counter reaches a number predetermined by thumbwheel switches, a 5A spdt relay changes state. The dot-matrix LED display, unlike 7-segment LED displays, provides accurate readout even when one LED fails. $300. **Kessler-Ellis Products Co.,** Atlantic Highlands, NJ 07716. Phone (201) 291-0500. **Circle No. 170**



PWM CURRENT AMP. Suitable for PWM motor-speed control, Model A6431-4A features bandwidth of 1 kHz and a form factor of 1.002. This unit utilizes reactive current flow to offer min. power consumption, and is fully protected from grounding and output shorts. Operating from a +40V dc supply and a signal-input voltage of 10V max., the device achieves a continuous rating of 0.2 hp. $135 (qty.). **Westamp, Inc.,** 1542-15th St., Santa Monica, CA 90404. Phone (213) 393-0401. **Circle No. 171**



PROGRAMMABLE ATTENUATORS. Suitable for remote operation, Models 2000 (75Ω) and 2100 (50Ω) accurately control attenuation over the frequency range of 2-500 MHz with 6-dB max. insertion loss. Voltage-controlled and continuously variable from 0 to >76 dB, these solid-state modules may act as RF switches or AM modulators (to 30 kHz). Control voltage may vary from 0-10V (Model 2000) or 0-12V (Model 2100), dc-30 kHz. $250. **Kay Elemetrics Corp.,** 12 Maple Ave., Pine Brook, NJ 07058. Phone (201) 227-2000. **Circle No. 172**

D/A. Ready to use without adjustments—or adding an external reference, output amplifier or trim pots—these 8-bit hybrids are packaged in hermetic 18-pin DIP's. Full-scale output settling time to ±1/2 LSB is 23 μsec (MN3013) and 1.5 μsec (MN3014), and ±1/2-LSB linearity is guaranteed over the full operating range of 0 to 70°C. Their complete interchangeability makes these devices well suited for hard-to-reach locations. MN3013, $22.50; MN3014, $24. **Micro Networks Corp.,** 324 Clark St., Worcester, MA 01606. Phone (617) 852-5400. **Circle No. 173**

FLOATING-POINT MODULE. Accepting 16 data bits and a 4-bit exponent, Model DD154 uses either automatic-justify or controlled-shift modes of operation to convert a floating-point value into scientific notation while maintaining full precision. Internally clocked, a full 16-bit operation takes <5 μsec and requires a single program instruction. $140; delivery, 60 days. **Interface Engineering, Inc.,** 386 Lindelof Ave., Stoughton, MA 02072. Phone (617) 344-7383. **Circle No. 174**

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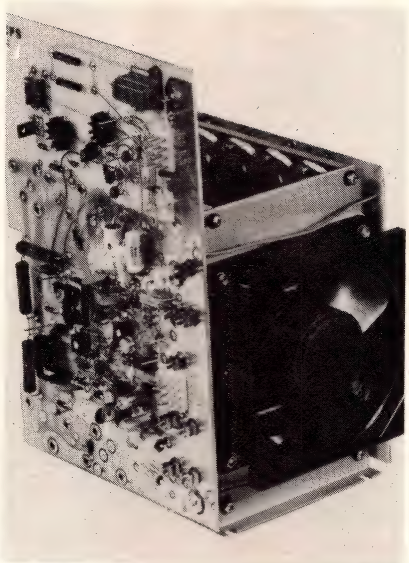

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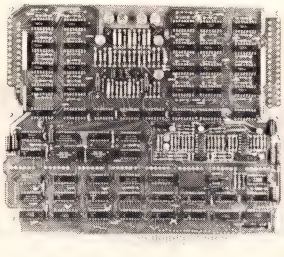
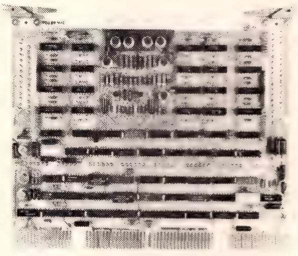
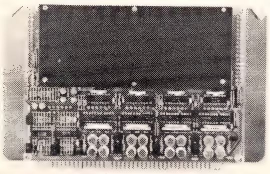


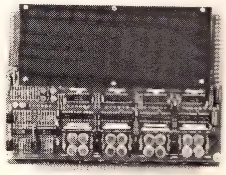
MM-16P 8K x 16



MM-1103 8K x 16



MM-6800 8K x 8



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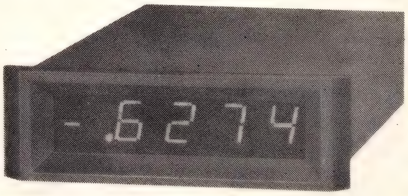

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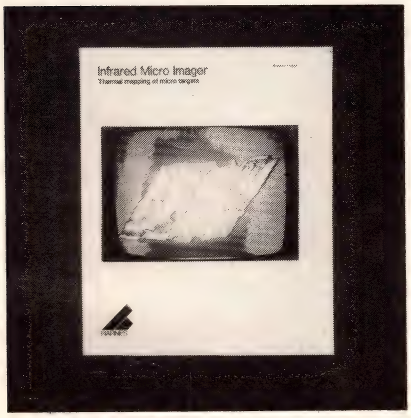
OP AMP. A 12-pg. applications brochure describes features and related user benefits of the CA3140. Included are 12 application circuits: function generator, meter driver and buffer amplifier, sample-and-hold, regulated supply, and others. Device ratings, characteristics, and performance curves are also presented. **RCA/Solid State Division,** Box 3200, Somerville, NJ 08876.
Circle No. 194

DISPLAY PANELS. Complete, ready-to-install panel modules are described in this 6-pg. brochure. An easy-to-use combination ordering/pricing chart lets users determine the exact cost of models with various options. Specs and mounting dimensions as well as legend, lamp, ground, terminal and other options are described in detail. **Data Panel, Inc.,** 7313 S. Washington Ave., Edina, MN 55435. **Circle No. 176**



INFRARED MICRO IMAGER. A 6-pg., 4-color brochure (Bulletin 12-970) describes the Model RM-50, which produces high resolution, real-time thermography of microscopic objects. This brochure details the RM-50's performance and available display modes, describes its operation and special features, and illustrates the obtainable results. **Barnes Engineering Co.,** 30 Commerce Rd., Stamford, CT 06904.
Circle No. 177

LCD'S. A 20-pg. booklet traces technology development and discusses the pros and cons of field-effect vs. dynamic scattering LCD's. Fully illustrated, the guide also contains information and diagrams on the company's line of instrument, clock and alphanumeric displays. An information-request form is included for those with specific application problems. **Shelly Associates,** 1562 Reynolds Ave., Irvine, CA 92714.
Circle No. 178

IC SOCKETS. This Selection Guide is a most useful tool for designers working with IC interconnects, providing design guidelines and application data for production, burn-in and test sockets; as well as plugs, cables and headers. An easy-to-follow chart, that lists major socket features and temp. ratings, will greatly ease proper socket selections. **Robinson-Nugent, Inc.,** 800 E. Eighth St., New Albany, IN 47150. **Circle No. 179**

PHOTOSENSITIVE DEVICES. Special-purpose versions of these devices are described in a 24-pg., 2-color booklet. Operating principles and applications are included, as well as specifications, performance characteristics, nomagraphs and lists of sensor-selection data, reference data and accessories. **ITT Electro-Optical Products Div.,** 3700 E. Pontiac St., Fort Wayne, IN 46803.
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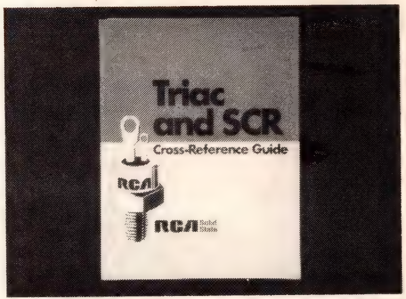

THYRISTORS. The 32-pg. "Triac and SCR Cross-Reference Guide," CRG-421, indicates RCA types recommended as replacements for 2100 industry triacs and SCR's. This booklet includes 2 cross-reference listings: RCA to commodity-type industry thyristors; and a comprehensive directory of industry-to-RCA replacements. **RCA/Solid State Div.,** Rte. 202, Somerville, NJ 08876.
Circle No. 181

STANDARDS. A 192-pg., 1976 catalog lists 6000 American National Standards and some 4000 international standards and recommendations. The ANSI standards are those approved through November, 1975; all listed publications are available from ANSI's Sales Department. This catalog also abstracts special publications on subjects such as metric conversion and consumer affairs, and includes a 28-pg. index, plus ordering information. **American National Standards Institute, Inc.,** 1430 Broadway, NY, NY 10018. **Circle No. 182**

THERMOCOUPLE THERMOMETER. Applications served well by the Heat-Prober™ are pictured in full color in this 8-pg. catalog W-576-D. The literature also describes and pictures the instrument's 28 interchangeable thermocouple probes, and gives full performance specs. **William Wahl Corp.,** 12908 Panama St., Los Angeles, CA 90066.
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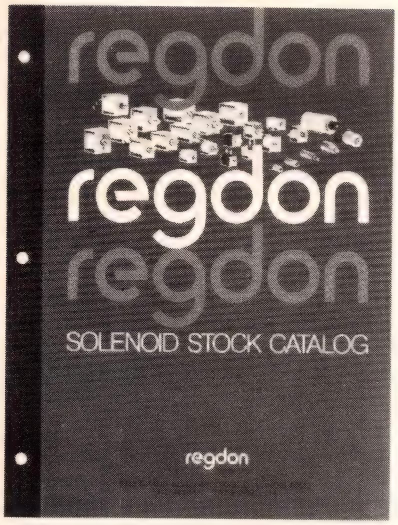

SOLENOIDS. This 6-pg. booklet describes 23 different solenoid types in detail. The coverage includes both box-frame and cylindrical versions in a variety of sizes and operating voltages. Force and stroke tables make it easy for the user to select the proper solenoid for his application. **Regdon Corp.,** 3713 Grand Blvd., Brookfield, IL 60513. **Circle No. 184**

SOLID STATE. This 16-pg. condensed catalog, technical data sheet T-1017, lists triacs, diacs, SCR's, solid-state and hybrid relays available from Teccor Electronics (formerly ECC Corp.). The catalog contains electrical and dimensional drawings, as well as part-number specifications on over 800 items. **Teccor Electronics, Inc.,** Box 669, Euless, TX 76039. **Circle No. 185**

CAPACITORS. The RF Capacitor Handbook is a 256-pg. manual covering basic circuit-design considerations and uses of RF capacitors. Discussions include high-frequency circuit design tips, characteristics of different designs, test methods, data characterizing RF capacitors, and ways to maximize gain, bandwidth and power. **American Technical Ceramics,** 1 Norden Lane, Huntington Station, NY 11746. **Circle No. 186**

4k RAM DILEMMA. Titled "The 4k RAM Dilemma: 16, 18 or 22 Pin?", this report will help designers select the best device for their requirements and priorities. The 18-pg. booklet advises no "best buy," but covers such factors as board-area savings, addressing and multiplexing. **Texas Instruments, Inc.,** Box 5012, Dallas, TX 75222. **Circle No. 187**

POWER SUPPLIES. Full-color Bulletin 76-2 describes the company's line of power supplies that have octal-plug mounting/interconnections. It contains specifications and pricing, and illustrates some typical applications. **Acopian Corp.,** Easton, PA 18042. **Circle No. 188**

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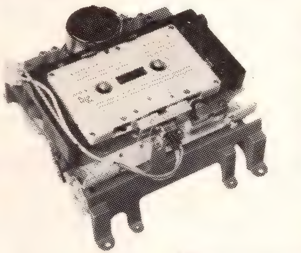
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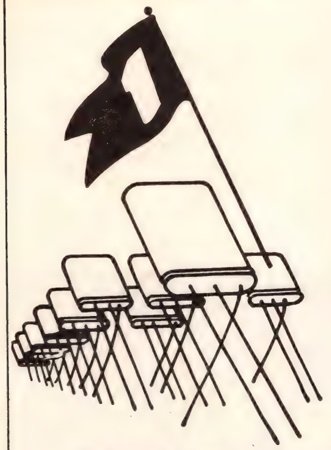

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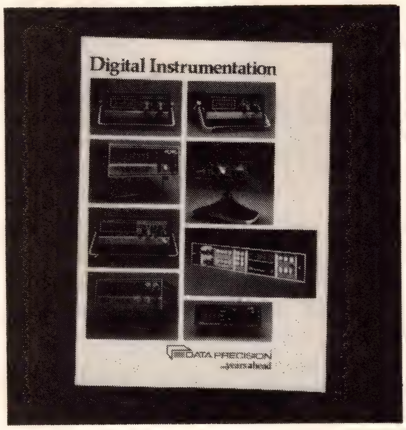

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DIGITAL INSTRUMENTATION. A 12-pg. catalog covering DMM's and timer/counters first presents a quick reference specification-comparison chart, then gives full specs on each of the instruments. **Data Precision Corp.,** Audubon Rd., Wakefield, MA 01880.
Circle No. 189

PENSION PLANS. Featuring 27 tables, most of them especially constructed for this 180-pg. book, "Everything you should know about pension plans" gives a wealth of information to help you avoid costly mistakes. The authors, Fay and Leo Young, use their IEEE experience to good advantage in treating this timely topic. Paperback, Library of Congress No. 76-017381, $4.95. **Bethesda Books,** Box 34567, Bethesda, MD 20034.
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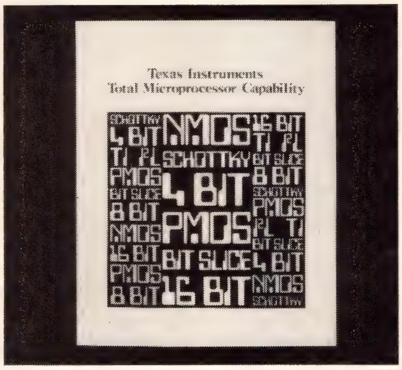

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μP CAPABILITY. This 8-pg., 4-color brochure describes TI's μP line that features technology and product information spanning a range of system-design needs from stand-alone μC systems to large, general-purpose computers. Included are all TI μP's, software, support hardware, and memory components. **Texas Instruments, Inc.,** Box 5012, Dallas, TX 75222. **Circle No. 190**

μP'S AND REMOTE STATIONS. The booklet "Supervisory System Programmable Remote Station Utilizing a μP" concentrates on the practical application of μP's in remote power-utility stations. Chapters detail a system that constantly monitors such stations, reporting alarm conditions when warranted. Sections cover word structure, security techniques, system organization and flow charting. $3.50. **IVECO,** 17402 Coronado Lane, Huntington Beach, CA 92647.
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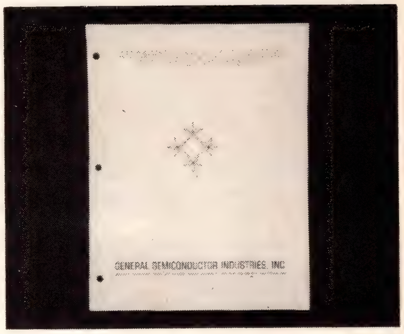

GENERAL SEMICONDUCTOR INDUSTRIES, INC

TRANSZORBS™. "A Comparison Report of TransZorbs versus Metal Oxide Varistors," provides data on published specs as well as comparative test data. This 8-pg. report defines key parameters to consider in specifying transient suppressors and explains how to compare the 2 types of devices. **General Semiconductor Industries, Inc.,** 2001 W. 10th Pl., Tempe, AZ 85281.
Circle No. 191

LOGIC ANALYZERS. A broad line of digital logic analyzers is described in a 6-pg. folder that lists the features of all available models, along with concise explanations as to how they can be applied. Photographs illustrate timing-diagram display outputs for different operational modes. **Biomation Corp.,** 10411 Bubb Rd., Cupertino, CA 95014.
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VOLTAGE REGULATION. The 16-pg. booklet "Theory, Design and Operation of Line-Voltage Regulation" discusses causes of irregular voltage, the subsequent problems and various solutions that provide constant voltage. A listing of 40 applications offers practical input on when and where line-voltage regulation is useful. **Sola Electric,** 1717 Busse Rd., Elk Grove Village, IL 60007.
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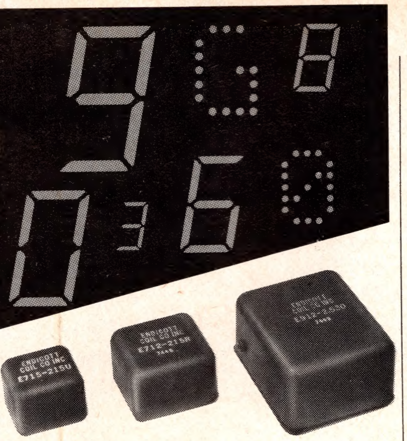

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The Designers Answer to Socket Contact Reliability

The new Molex closed entry LSI socket

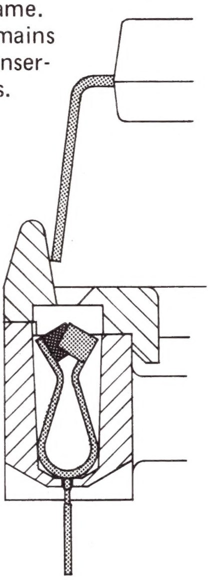
Molex is proud to have ranked 2nd among socket manufacturers in performance in a 1975 mini-computer manufacturers test study. Why are we proud to be a runner-up? Well, the winner was a screw machine type part at three times the cost, that's why!! Proven reliability, quality features, and the economical price you have wanted in a closed entry socket is now available from . . . Molex, Incorporated.

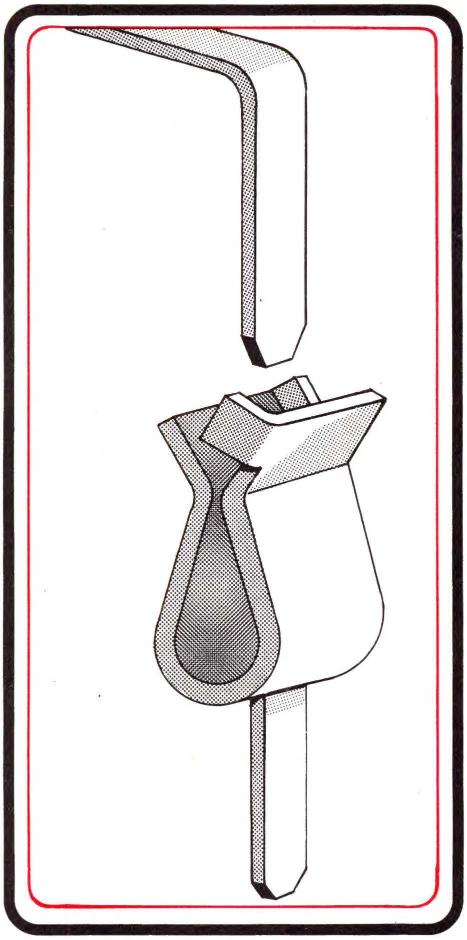
The 6097 Closed Entry LSI Socket combines the time-tested quality of the Molex Soldercon™ 1938 Dual Beam contact with a new 94V-0 flame retardant polyester housing. This new combination allows insertion and withdrawal of fragile LSI's without damage while maintaining sufficient normal force for a reliable low-level electrical contact.

Key Features:

The Molex Soldercon™ features side bearing contacts. These contacts offer better overall contact reliability, mechanically, and electrically, because we are making contact with the main surface of the lead frame. Contact resistance remains constant after many insertions and withdrawals.

The 94V-0 black housing design incorporates many desirable features such as the closed entry cap . . . a tapered lead-in ramp to insure positive positioning of the LSI in the contact areas, and a closed socket base to prevent solder wicking during wave soldering.

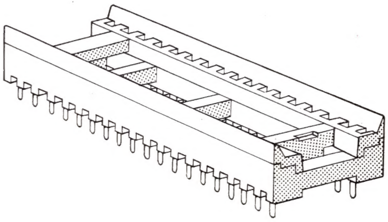




Options:

The 6097 is available in 24, 28, and 40 positions on .100 x .600 spacing. Contact platings and materials are available in tin, selective gold, and overall gold over brass or phos bronze material.

The 6097-N could be the answer to your socketing headaches at a very competitive price. For example, a 24 position socket at the 5,000 piece price level costs 24¢ each in tin.



Literature:

For your FREE 6-page Socket flyer including line drawings and specifications of the Molex line, call (312) 969-4550; or write Molex Incorporated, 2222 Wellington Ct., Lisle, IL 60532.

Molex Service:

These sockets are backed by the Molex reputation for excellence in engineering, reflected in the quality and reliability of Molex affordable technology in interconnection and switch products.

Molex has a nationwide network of representatives and franchised distributors to handle your off-the-shelf and large quantity orders. Field engineers are at your service to solve your tooling problems.

molex® . . . *Affordable Technology*

For more information, Circle No. 2

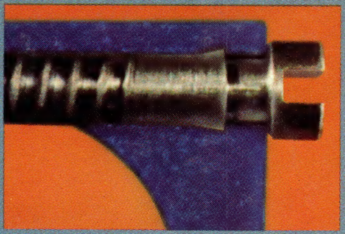
Swage-Bond™ . . . a revolution in trimmer reliability!

Swage-Bond™ eliminates pin termination failure, provides more reliable tempco. Microphotograph shows trimmer element magnified 20X.

. . . here today at no extra cost in every Trimpot® Potentiometer

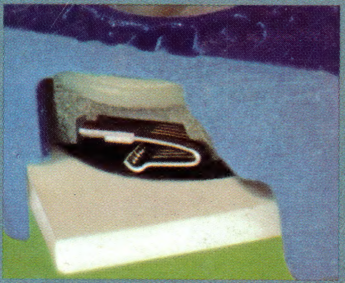
Historically, pin-to-element termination problems have been one of the primary causes of trimmer failure . . . especially during handling and PC board process operations. Bourns exclusive Swage-Bond™ process virtually eliminates pin termination failure . . . truly a revolution in trimmer reliability. Furthermore, Swage-Bonding results in a marked improvement in temperature coefficient consistency.

Other trimmer manufacturers utilize a simple clip-on termination. Some solder this connection, some rely on tension pressure alone. In the Swage-Bond process, the P.C. pins are secured **through** the substrate, with a high-pressure compression swage on both top and bottom sides. The pressure of the swage locks the pin solidly into the element, and thoroughly bonds it to the thick-film termination material.



The seal that seals . . . without springback

Bourns trimmers stay sealed when others fail. We know. We've tested them all. Bourns uses a chevron-type sealing technique, that seals without O-rings . . . eliminating the windup and springback that frequently occurs with such seals. The result is faster and more precise adjustability . . . with a seal that really works.



Wrap-around wiper for better setting stability

Bourns multi-fingered, wrap-around wiper delivers more consistent, more reliable performance. The unique design significantly reduces CRV fluctuations and open circuit problems due to thermal and mechanical shock . . . by maintaining a constant wiper pressure on the element. Compare the ruggedness of Bourns design with the common "heat-staked" wiper designs. Compare performance. Specify Bourns.

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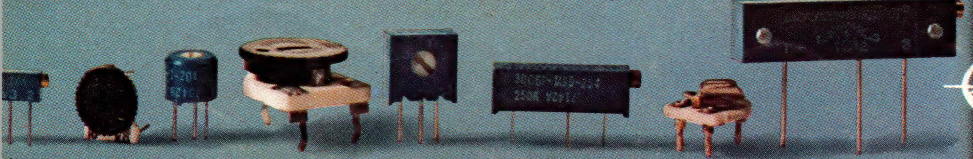
Send for a copy of our new engineering report on TRIMMER PERFORMANCE. Tell us about your application, and we'll provide qualification samples that best suit your needs.

Bourns reliability is available at ordinary prices . . . off-the-shelf from nearly 100 local distributor inventories . . . plus our largest-ever factory stock. TRIMMER PRODUCTS, **TRIMPOT PRODUCTS DIVISION,** BOURNS, INC., 1200 Columbia Avenue, Riverside, California 92507. Telephone 714 781-5320 — TWX 910 332-1252.



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